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HEATING AND VENTILATION OF MODERN HOUSING

Alberta
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Innovative Housing Grants Program

HEATING AND VENTILATION OF MODERN HOUSING

March 1987

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

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As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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TABLE OF CONTENTS

Page

LIST OF TABLES iv

LIST OF FIGURES v

EXECUTIVE SUMMARY vi

1.0 INTRODUCTION 1

2.0 FINDINGS OF THE LITERATURE REVIEW 2

2.1 Air Quality in Housing 2
2.1.1 Introduction 2
2.1.2 Sources of Indoor Air Pollution 2
2.1.3 Pollutants 3
2.1.4 Acceptable Pollutant Levels 4
2.1.5 Control of Indoor Air Pollution 4

2.2 Safety and Backdrafting 5
2.2.1 Introduction 5
2.2.2 Causes 5
2.2.3 Air Requirements of Equipment and Appliances 5
2.2.4 Cures 6

2.3 Moisture Control 8
2.3.1 Introduction 8
2.3.2 Sources of Moisture 8
2.3.3 Problems of Associated With Moisture 8
2.3.4 Solutions 9

2.4 Ventilation and Infiltration 9
2.4.1 Introduction 9
2.4.2 Assessment of Natural Ventilation Rates 9
2.4.3 Mechanical Ventilation Requirements 10

2.5 Heat Recovery Ventilators 10
2.5.1 Introduction 10
2.5.2 Operational Problems 10

2.6 Conclusions 11
2.6.1 Air Quality in Housing 11
2.6.2 Safety and Backdrafting 11
2.6.3 Moisture Control 11
2.6.4 Ventilation and Infiltration 12
2.6.5 Heat Recovery Ventilators 12

3.0 ENGINEERING ANALYSIS 13

3.1 Introduction 13

3.2 Payback Analysis of Energy Conservation Measures 13
3.2.1 Introduction 13
3.2.2 Computer Model of Base Building 16
3.2.3 Analysis of Energy Conservation Opportunities 16

3.3 Backdrafting 19
3.3.1 Introduction 19
3.3.2 Principals of Gas Vent Systems 20
3.3.3 Testing for Backdrafting and Spillage 22
3.3.4 Standata 85-DI-017 23

3.4 Moisture 23
3.4.1 Introduction 23
3.4.2 Graphical Analysis to Determine Permissible Relative Humidity Levels 24
3.4.3 Dehumidification Air Requirements 24
3.4.4 Annual Cost of Dehumidification Air 28
3.4.5 Dehumidification Air Changes Necessary to Prevent Condensation In Test House One 31

3.5 Natural and Forced Ventilation Rates 33
3.5.1 Natural Ventilation 33
3.5.2 Forced Ventilation Rates 34

3.6 Conclusions 35
3.6.1 Backdrafting 35
3.6.2 Moisture 35
3.6.3 Natural and Forced Ventilation Rates 36
3.6.4 Payback of Energy Conservation Measures 36

4.0 DESIGN OF HEATING AND VENTILATING SYSTEMS FOR HOUSES 37

4.1 Introduction 37

4.2 Mechanical System Design Criteria 37

4.3 Principals of Heating and Ventilating Systems for Housing 37

4.4 Balanced Ventilation System 40
4.4.1 Introduction 40
4.4.2 Economizer System 40
4.4.3 Heat Recovery Ventilators 40

4.5 Negative Pressure Systems 42
4.5.1 Introduction 42
4.5.2 Sealed Furnace Room 42
4.5.3 Atmospherically Uncoupled Appliances 44
4.5.4 Induced Draft Fan 44

4.6 Duct System Design Considerations 45

5.0 CONCLUSIONS AND RECOMMENDATIONS 48

5.1 Introduction 48

5.2 Air Quality in Housing 48

5.3 Backdrafting 48

5.4 Moisture 49

5.5 Cost Effective Levels of Insulation 49

5.6 Cost Effective Combustion Appliances 49

5.7 Air Tightness 49

5.8 Ventilation Strategies 50

BIBLIOGRAPHY

APPENDICES

APPENDIX A - Summaries from the Literature Review
APPENDIX B - Energy Bills for Test Houses
APPENDIX C - Example Computer Simulations of Test House "As Is"
APPENDIX D - Standata 85-DI-017
APPENDIX E - Dehumidification Air Computer Program
APPENDIX F - U of A Test Data From the Ellerslie Research Facility

LIST OF TABLES

		Page
TABLE 2.1	Representative Air Requirements and Pressure Differentials Associated with Equipment and Appliances	7
TABLE 3.1	Results of Analyses of Conservation Opportunities	18
TABLE 3.2	Permissible Relative Humidities for Single Glazing	27
TABLE 3.3	Permissible Relative Humidities for Double Glazing	27
TABLE 3.4	Permissible Relative Humidities for Triple Glazing	27
TABLE 3.5	Dehumidification Air Requirements for Single Glazing	29
TABLE 3.6	Dehumidification Air Requirements for Double Glazing	29
TABLE 3.7	Dehumidification Air Requirements for Triple Glazing	29
TABLE 3.8	Dehumidification Air Required to Prevent Condensation on Glazing Per Pound of Moisture Added to the Space Per Hour	32
TABLE 3.9	Cost to Heat Sufficient Dehumidification Air To Prevent Condensation on Glass in Edmonton	33

LIST OF FIGURES

		Page
Fig 3.1	Test House One - Main Floor Plan	14
Fig 3.2	Test House Two - Main Floor Plan	15
Fig 3.3	Gas Vent System Schematic	21
Fig 3.4	Temperature Gradient, Single Glass	25
Fig 3.5	Temperature Gradient, Double Glass	26
Fig 3.6	Temperature Gradient, Triple Glass	26
Fig 3.7	Dehumidification Air Requirements, Single Glazing	30
Fig 3.8	Dehumidification Air Requirements Double Glazing	30
Fig 3.9	Dehumidification Air Requirements Triple Glazing	31
Fig 4.1	Schematic of Typical Heating and Ventilating System for Housing	38
Fig 4.2	Economizer System	41
Fig 4.3	Sealed Furnace Room	43
Fig 4.4	Atmospherically Uncoupled Appliances	46
Fig 4.5	Induced Draft Fan	47

EXECUTIVE SUMMARY

Introduction

This study examines heating and ventilation in modern housing. The major issues examined are as follows: indoor air quality, backdrafting of combustion appliances, moisture control, ventilation and infiltration, and the economics associated with various energy conservation techniques.

Study Methods

The study has been conducted in several phases. Initially, a computerized database search was carried out to locate appropriate references. These references were reviewed and summarized. The summaries are contained in Appendix A of this report. Conclusions based on the literature review are contained in Chapter 2 of this report.

Issues deserving more study were examined further during the engineering analysis phase of the work.

The National Research Council's Hotcan-2000 computer program was utilized to examine the economic implications of various construction techniques and retrofits.

Backdrafting of combustion appliances is examined.

Graphical methods were utilized to examine factors affecting acceptable moisture levels within a building. A computer program was utilized to quantify dehumidification air requirements for various moisture generation rates within the building. The annual cost of dehumidification air is quantified.

Required ventilation rates are outlined. The contribution of infiltration under various conditions are calculated and discussed.

Conclusions and Recommendations

Standard houses derive a significant portion of their ventilation from the uncontrolled infiltration of outside air. Retrofitting these houses to "airtight" standards without regard to the existing ventilation system can result in elevated indoor pollution levels and hazardous backdrafting.

Constructing new houses to "airtight" standards cannot be justified strictly on the basis of the potential energy saving. Similarly, the installation of heat recovery ventilators, to accommodate present minimum ventilation rates, is not economically viable.

More research into the question of acceptable levels of various indoor pollutants is required. Eliminating tobacco smoking would eliminate a major source of indoor air pollution. In the meantime, minimum ventilation requirements should be increased.

Energy conservation efforts should be both economically viable and safe. If existing building envelopes are tightened, induced draft fans on the vents of atmospheric gas-fired appliances should be part of the retrofit. In addition, fireplaces should be atmospherically uncoupled.

New buildings with "airtight" envelopes should be equipped with forced draft or otherwise uncoupled appliances.

If higher minimum ventilation rates are established heat recovery ventilators may become more economically viable.

1.0 INTRODUCTION

This paper examines the inter-relationship between the building envelope in "airtight" housing and heating and ventilation systems.

The amount of energy utilized by a building can be decreased by reducing the rate of natural air infiltration. This has resulted in new houses being built with higher levels of air tightness. In addition, existing houses are being retrofitted to reduce the natural air infiltration rate. Much of this work has been undertaken without examining how the reduced air infiltration rates affect the buildings mechanical systems. Backdrafting of natural gas fired appliances, reduced indoor air quality and moisture problems can result.

A literature search has been undertaken to collect and review existing literature on backdrafting, indoor air quality, moisture control, and ventilation. The literature reviewed is listed in the bibliography. Summaries of relevant literature are included in Appendix A. An assessment of the literature reviewed forms Chapter Two.

Engineering analyses were then undertaken to examine the following:

- backdrafting of combustion appliances,
- outside air change rates required to prevent condensation on single, double, and triple glazing at various outdoor conditions,
- forced and natural ventilation rates, and
- payback of various energy conservation measures.

The results of these analyses are contained in Chapter Three of this report.

The findings of the engineering analyses were utilized to produce guidelines for mechanical systems in "airtight" housing. These guidelines are explained in Chapter Four of this report.

General conclusions and recommendations resulting from this study are contained in Chapter Five.

2.0 FINDINGS OF THE LITERATURE REVIEW

2.1 AIR QUALITY IN HOUSING

2.1.1 Introduction

Indoor air pollution is increasingly becoming a problem in modern society. People spend the majority of their time indoors and are being exposed to increasing levels of indoor air pollution. These pollution levels are increasing as a result of off-gassing from new building products and consumer products, and as a result of the tendency to reduce air infiltration in new and existing buildings.

The literature on indoor air pollution identifies a seemingly endless number of pollutants. It is beyond the scope of this study to report on all of the potential pollutants.

A telephone conversation with Mr. Peter Russel of Canada Mortgage and Housing Corporation, revealed that Health and Welfare Canada is in the process of defining new indoor air quality standards. The approach adopted by Health and Welfare Canada is to define 18 pollutants or groups of pollutants. Of those groups the following will be assigned allowable limits:

- carbon dioxide, carbon monoxide, nitrogen dioxide, ozone, formaldehyde, radon, moisture, sulphur dioxide, total aldehydes and particulates.

The new maximum allowable levels of pollutants were not available at the time of our conversation. A private conservation with Dr. Vic Armstrong of Health and Welfare Canada in April 1987, indicated that quidelines should be available in two to six months.

This section outlines the sources of indoor air pollution. The major pollutant groups are discussed. Acceptable pollutant levels as defined by the American Conference of Industrial Hygienists and ASHRAE are discussed. Long term and short term control strategies are discussed.

2.1.2 Sources of Indoor Air Pollution

Numerous human activities create or aggravate indoor air pollution. One of the major sources of indoor air pollution is cigarette smoking which produces particulate and gaseous pollutants. Over 1000 different compounds have been identified in cigarette smoke.

A second major source of indoor air pollution is the use of indoor combustion devices including gas stoves, fireplaces, and wood and coal stoves. These appliances increase the carbon monoxide, nitrogen dioxide, and particulate concentrations in the indoor air.

Occupant activities, including vacuuming and the use of aerosols and other chemicals, introduce numerous particulate and gaseous pollutants into the air. The number of possible pollutants is increasing daily as new products are introduced into the marketplace.

Off-gassing from building materials is responsible for increasing the levels of radon, asbestos fibres, formaldehyde and other organic vapours in the indoor environment.

2.1.3 Pollutants

Radon is a gas which is part of the uranium-238 decay chain. Radon decays radioactively to form four short-lived daughter products, Polonium-218, Lead-214, Bismuth-214 and Polonium-214. These daughter products attach themselves to airborne dust particles. These particles can reportedly cause lung cancers if they are inhaled. The Atomic Energy Control Board has established a maximum permissible concentration of 4 nano-curies per cubic metre.

Formaldehyde is an organic chemical used extensively in building materials and furnishings. Formaldehyde concentrations in the air tend to increase as the relative humidity increases. Formaldehyde causes irritation of the skin, eyes and throat. Humans tend to be more sensitive to formaldehyde as a result of prolonged exposure. Health and Welfare Canada recommends a maximum allowable concentration of 2 parts per million (ppm). The American Conference of Governmental Industrial Hygienists has adopted this value. Most people can detect formaldehyde at levels below 1 ppm.

Nitrogen oxides result from unvented indoor combustion appliances, and from smoking. Nitrous oxide causes burning and choking sensations above 25 ppm. Unconsciousness can occur after prolonged exposure. Nitrogen dioxide is more toxic than nitrous oxide. Exposure to concentrations above 0.5 ppm can produce symptoms of emphysema. Nitrogen dioxide produces increased olfactory recognition thresholds and causes a metallic taste. The American Conference of Governmental Industrial Hygienists has adopted a threshold limit value of 5 ppm for nitrogen dioxide. The Canadian Ambient Air Quality Standard for a twenty-four hour period is 0 to 110 parts per billion.

Carbon monoxide is a colourless, odourless, and tasteless gas that is extremely poisonous. Carbon monoxide is produced by incomplete combustion of fossil fuels. The Canadian Ambient Air Quality Standard average over eight hours is between 5 and 12.5 ppm. The American Conference of Governmental Industrial Hygienists has adopted a threshold limit value of 50 ppm.

Carbon dioxide is a colourless gas produced by combustion and respiration. High levels in excess of 50,000 ppm can cause asphyxiation. Concentrations above 5,000 ppm may have adverse health effects, but more research is required to confirm this. Canada, at present, has no indoor air standard for carbon dioxide. ASHRAE recommends a maximum level of 2,500 ppm. The American Conference of Governmental Industrial Hygienists has adopted a threshold limit value of 5,000 ppm.

Particulates are introduced into the air from a myriad of sources including smoking, vacuuming, plants, pets, insects, fireplaces, etc. The health effects vary according to the source of the particulates. These pollutants can aggravate the allergic reactions of susceptible individuals. The Canadian Ambient Air Quality Standard average over 24 hours is 0 to 120 microgram per cubic metre.

2.1.4 Acceptable Pollutant Levels

Appendix C of ASHRAE standard 62-1981 recommends the time weighted average (TWA) allowable concentration for the general public be reduced to one-tenth of the adopted TWA values for industrial workers. This reduction is recommended to accommodate the increased duration of exposure generally experienced by the general public compared with the industrial worker's exposure. This reduction also accounts for a more varied general population that is not medically monitored as closely as the industrial population. A complete listing of TWA allowable concentrations is outlined in "Industrial Ventilation"1.

AHRAE Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality" lists the National Ambient Air Quality Standards in Table 1. Additional Ambient Air Quality Guidelines are listed in Table 2. Table 4 lists selected guidelines for air contaminants of indoor origin. Many concentrations and exposure times are absent from this table, indicating that further research into this problem is required.

2.1.5 Control of Indoor Air Pollution

There are three basic methods of controlling indoor air pollution. The most desirable method is the removal of the pollutant sources. The second method is to dilute the pollutants with fresh air. The third, and probably the most expensive option, is to remove the pollutants within the building air handling units.

In the long term legislation may result in the reduction of the sources of indoor air pollution. This is the most desirable solution.

---

1 #01 Conference of Governmental Industrial Hygienists

In the short term, with pollution emanating from building materials, furnishings, and human activities, the solution is the introduction of outside air to reduce the concentration of indoor pollutants to acceptable levels. The amount of dilution air required depends on the types and generation rates of indoor pollutants. This question is explored more fully in Chapters 4 and 5.

2.2 SAFETY AND BACKDRAFTING

2.2.1 Introduction

Flue spillage and backdrafting of furnaces and water heaters has always been a potential hazard to homeowners using fossil fuels, coal, or wood. Flue gases contain lethal concentrations of carbon monoxide.

2.2.2 Causes

Modern housing is equipped with fuel-fired furnaces and water heaters, washroom exhaust fans, kitchen exhaust fans, central vacuum systems, clothes driers. These devices all require a source of outside air. Each device also has a tendency to impose a different level of negative pressure across the building envelope. The competition among these air consuming devices can lead to backdrafting or flue spillage. For example, a bathroom exhaust fan can impose a greater negative pressure than the furnace chimney buoyancy. This will lead to chimney backdrafting.

Improper equipment installation can also lead to backdrafting. For example, the trend towards conversion from oil fuel to natural gas has led to inappropriate retrofits. Natural gas fired appliances have been connected to unlined masonry chimneys. This can lead to chimney deterioration and eventually to chimney blockage.

Outside air for equipment use to be provided by infiltration. Modern housing tends to be more airtight than houses built in the past. This, in conjunction with the trend towards air tightening existing houses creates or aggravates the tendency towards backdrafting in furnaces, water heaters and fireplaces.

2.2.3 Air Requirements of Equipment and Appliances

Outside air is required to replace air that is removed from a house by various appliances and pieces of equipment. This outside air replaces combustion air required by furnaces, domestic water heaters, and fireplaces. Outside air is also required to replace air that is removed by kitchen and washroom exhaust fans which control pollutant levels within the building.

Central vacuum systems and clothes dryers that discharge air to the outdoors also require replacement air from outdoors.

To complicate matters further, the devices and appliances previously mentioned impose different pressure differentials across the building envelop. Combinations of devices result in air requirements and pressure differentials that are not necessarily the arithmetic sum of the individual requirements. Every fan has a fan curve associated with it. This fan curve defines the amount of air that flows through the fan at various levels of resistance to flow. In general, the fan volume increases as the resistance to flow decreases. Fan curves are not generally linear and the shape of the curve varies with the type of fan.

Table 2.1 on page 7, outlines representative air requirements and static pressures associated with various appliances and types of combustion equipment. These figures were derived from various sources which are cited.

The values outlined in Table 2.1 are meant to provide the reader with orders of magnitude. Although fan curves are readily available, further research is required to develop flow-pressure curves for other devices. These curves would be helpful in analyzing the flows and pressure differentials associated with the operation of combinations of devices.

2.2.4 Cures

Downdrafting can be cured by mechanically providing enough air to ensure a slight positive pressure within the building under all modes of operation.

Fireplaces should be uncoupled from the house by installing airtight glass doors and an outside air supply.

TABLE 2.1

REPRESENTATIVE AIR REQUIREMENTS AND PRESSURE DIFFERENTIALS ASSOCIATED WITH EQUIPMENT AND APPLIANCES

	Size		Estimated Airflow		Pressure	
Device	kW	(MBH)	l/s	(CFM)	Pa	(in.wc)
Atmospheric Gas-Fired Furnace(a)	20.5	(70)	18(b)	(38)	27(c)	(0.11)
	26.4	(90)	23(b)	(49)	27(c)	(0.11)
	30.8	(105)	27(b)	(57)	27(c)	(0.11)
	39.6	(135)	35(b)	(74)	27(c)	(0.11)
Atmospheric Gas-Fired Water Heater(d)	11.7	(40)	10(b)	(21)	27(c)	(0.11)
Wood Stove (open)	19.6	(67)	40(e)	(85)	53(f)	(0.21)
Wood Stove (airtight)	--		20(e)	(42)	53(f)	(0.21)
Wood Fireplace	56.6	(193)	115(e)	(244)	53(f)	(0.21)
Clothes Dryer (cold) (g)	--		50	(106)	100	(0.4)
	--		37	(78)	160	(0.64)
Range Hoods	100-250mm (4"-10")		50-300 (106-636)		30-300 (0.12-1.2)	
Bathroom Fans(g)	75-200mm (3"-8")		40-150 (85-318)		30-300 (0.12-1.2)	
Jenn Air Stove(g)	Model C201		165	(350)	0	(0)
			120	(255)	150	(0.6)
			20	(42)	240	(0.96)
Central Vacuum (vented to outdoors)(h)	1.49	(2HP)	54	(115)	29,394	(106)
	1.86	(2.5HP)	49	(105)	27,390	(110)
	2	(2.8HP)	47	(100)	33,864	(136)
Induced Draft Fans(i)	75mm	(3")	22.7	(48)	8.47	(0.034)
	100mm	(4")	33.9	(72)	10.46	(0.042)
	125mm	(5")	33.9	(72)	10.71	(0.043)
	150mm	(6")	32.1	(68)	10.21	(0.041)

(a) Flamemaster FM series
(b) Calculated using Table 2, Page 27.5, 1083 ASHRAE
(c) Table 7A, Page 27.8, 1983 ASHRAE, 149oC (300oF) gas temp. rise, 6 m (20 ft.) chimney
(d) 30 US gallon, Jetglas Model M30T5LN
(e) Unpublished First Draft CAN/CGSB-51.71-M

TABLE 2.1 (cont'd)

(f) Table 78, Page 27.8, 1983 AHSRAE, 760oC (1400`F) gas temp rise, 6 m (20 ft.) chimney
(g) The Effect of Exhaust Fans and Remedial measures on House Depressurization, SRC Publication No. R-823-4-E-86, April 1986
(h) Beam Vacuum Company
(i) Field Controls Model DI-1, 321oC (270`F) Flue Gas

2.3 MOISTURE CONTROL

2.3.1 Introduction

The incidence of moisture problems in buildings is becoming more common as the level of airtightness increases. Moisture problems can result in expensive structural damage. For this reason, special attention should be paid to moisture control when designing airtight housing or when tightening existing houses.

2.3.2 Sources of Moisture

Moisture is added to the indoor environment from several sources. Moisture "evaporates" from building materials such as wood and concrete for several years after construction. Fortunately the rate of moisture production decreases with time.

Human metabolism adds moisture to the indoor environment. The larger the number of people and the greater their level of activity, the more moisture is added to the space.

Human activities such as cooking, laundry and showers add moisture to the indoor environment.

Groundwater can find its way into the indoor environment from the basement. Crawl spaces without a concrete or other sufficient floor moisture barrier can add a significant amount of moisture to the interior of a house.

2.3.3 Problems Associated with Moisture

Moisture problems in residences fall into two general categories, concealed condensation and surface condensation. Surface condensation occurs when the temperature of any surface falls below the dewpoint of the air surrounding it. Water from the air condenses on the surface until enough moisture is removed from the air to raise the dewpoint above the surface temperature. Condensation on windows in winter is an example of surface condensation. Surface condensation can result in mould and mildew on building walls and ceilings. Surface condensation should be considered a warning of potentially serious future moisture problems.

Concealed condensation results from moisture laden air penetrating building assemblies such as walls or attic spaces. Moisture condenses from the air as it moves from the warm interior towards the colder exterior. A point is reached within the wall assembly where the air temperature falls below its dewpoint temperature and condensation occurs. Concealed condensation can result in dry rot and other serious structural damage.

2.3.4 Solutions

Indoor air relative humidity should be kept down to acceptable levels. This can be accomplished by ventilation using drier outside air. Elimination or reduction of moisture sources should also be considered. The installation of a continuous air barrier will prevent concealed condensation. A negative pressure within the building (as compared to outdoors) will also prevent moisture laden air from migrating into building assemblies.[1]

2.4 VENTILATION AND INFILTRATION

2.4.1 Introduction

Ventilation is required to provide fresh air for occupants and combustion equipment. Ventilation with fresh air is also required to keep moisture and indoor pollution levels down to acceptable levels. The importance of mechanical ventilation increases with the level of airtightness of the building shell.

2.4.2 Assessment of Natural Ventilation Rates

A large amount of research has been undertaken to quantify natural ventilation rates. Various approaches have been taken towards this goal. Many studies have attempted to construct mathematical models based on wind velocity and direction and on buoyancy effects. Other studies use tracer gas decay methods or use fan depressurization techniques. Mathematical regression on data from several buildings are performed in an attempt to come up with a mathematical relationship that would apply to other buildings.

These studies have invariably met with limited success. The problem is that different builders construct houses differently.

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[1] #01 This measure can cause dangerous backdrafting, downdrafting and flue spillage

It is almost impossible to predict the sizes, shapes, and distribution of air paths in building envelopes.

2.4.3 Mechanical Ventilation

ASHRAE standard 62-1981 requires for residential facilities a minimum of 10 CFM (5 litres per second) for general living areas, bedrooms, and all other rooms independent of room size. Kitchens require 100 CFM (50 l/sec) and bathrooms require 50 CFM (25 l/sec) installed capacity for intermittent use.

Standata bulletin #81-T-015, developed jointly by Alberta Building Standards Branch and the Plumbing and Gas Safety Services Branch indicates that 20 volumes of combustion and dilution air are required for every unit volume of natural gas. This bulletin presents a sketch which details an acceptable combustion air supply. A duct bringing outside air to the return air duct of the furnace is recommended. In addition, a heated air opening from the furnace supply air duct in the vicinity of the furnace is required. The size of the outside air duct is determined by the input rating(s) of the gas-fire appliance(s). A two-speed fan motor is suggested to ensure an adequate air supply for the domestic hot water heater. This bulletin stresses that additional outside air is required for washroom fans, kitchen fans, fireplaces, etc.

2.5 HEAT RECOVERY VENTILATORS

2.5.1 Introduction

Tightening building envelopes in an attempt to increase energy efficiency may aggravate indoor air pollution. Mechanically providing adequate fresh air to keep moisture and pollutant levels down to acceptable levels may cost as much from an energy point of view as the initial air tightening saved. Heat recovery ventilators are one method of delivering an adequate supply of fresh air to a building at a reasonable cost.

2.5.2 Operational Problems

Although there are potential advantages arising from the use of heat recovery ventilators, field experience has pointed out some operational problems. At low outdoor temperatures, frosting of the heat recovery core has been a problem. A built-in defrost cycle can remedy this problem.

Care must be exercised in the design and installation of heat recovery ventilators. The location of the air intake should be chosen to avoid introducing polluted air into the building. Excessive amounts of ductwork can lead to poor ventilator performance. The supply and exhaust air quantities should be balanced to avoid negative pressures which could lead to appliance flue spillage.

2.6 CONCLUSIONS

2.6.1 Air Quality in Housing

The long term adverse health effects of low levels of various pollutants are not known. Medical research should be undertaken to address these unknowns. In the meantime, maximum allowable levels for various pollutants must be established as a first step.

The immediate solution to indoor air pollution is to control it through dilution with cleaner outdoor air. The long term solution is source control. Potential sources of indoor air pollution should not be incorporated into the building shell or used in finishes or furnishings.

Smoking is a major source of indoor air pollution. Large amounts of fresh air are required to keep these pollutants down to acceptable levels.

2.6.2 Safety and Backdrafting

The potential for backdrafting, downdrafting, and flue gas spillage increases with the level of air tightening of the building envelope. For this reason, an adequate supply of fresh air under all operating conditions is essential.

Uncoupling of all fuel burning devices from the building represents one possible solution. The use of forced draft natural gas-fired appliances would eliminate the safety concerns associated with furnaces and water heaters.

A conflict exists between the requirement for positive building pressure to prevent backdrafting and a negative pressure required to prevent concealed condensation. Uncoupling combustion devices from the building would eliminate this conflict.

2.6.3 Moisture Control

Electrically heated houses appear to have more moisture related problems than houses equipped with a fresh air intake and a forced air heating system.

Moisture problems related to construction materials decrease over a period of time.

Source control of moisture is essential in modern housing. A vapour barrier should be installed under the floor slab in new housing.

Concealed condensation can be reduced by ensuring a high degree of air tightness in the building envelope. A negative pressure across the building envelope will also reduce the potential for concealed condensation. This approach should only be considered if all combustion appliances are forced draft, or if they are uncoupled from the building.

2.6.4 Ventilation and Infiltration

In older leaky houses, natural ventilation has been considered adequate to control indoor air pollution. As building air tightness is increased, the requirement for mechanical ventilation increases.

2.6.5 Heat Recovery Ventilators

Heat recovery ventilators should be installed if they are proven cost effective. The seasonal efficiency of these devices appears to be less than the manufacturers have claimed. The major operational problems with these devices are frosting and air imbalance.

3.0 ENGINEERING ANALYSIS

3.1 INTRODUCTION

This section examines backdrafting of combustion appliances, ventilation rates required to control moisture, forced and natural ventilation rates and the economics of various energy conservation measures.

3.2 PAYBACK ANALYSIS OF ENERGY CONSERVATION MEASURES

3.2.1 Introduction

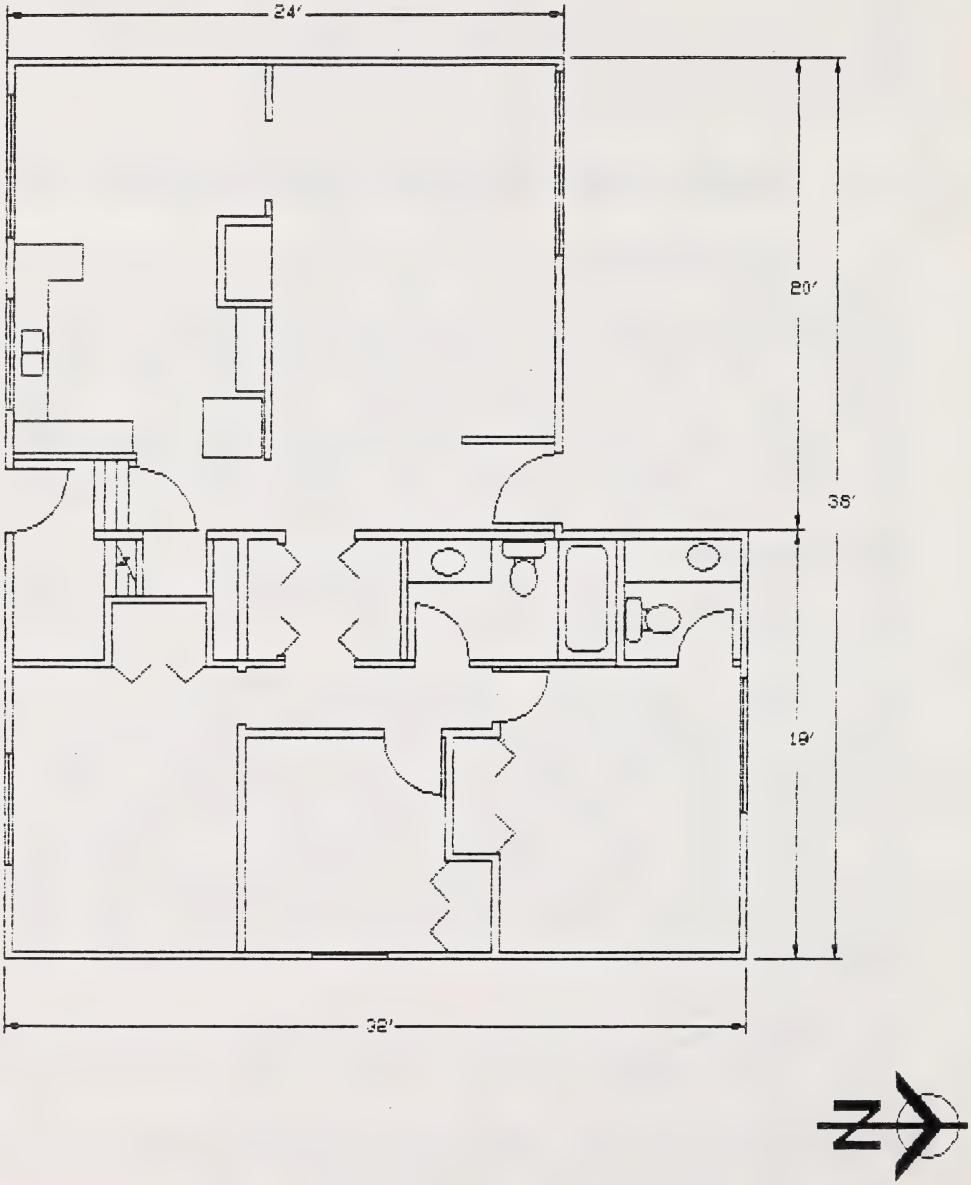
TEST HOUSES
Two existing houses, with documented energy bills, were analyzed during this study. The buildings were modelled mathematically using the Hotcan computer program. An "As Is" simulation was undertaken to confirm the validity of the model. The envelope and mechanical system characteristics of House One was then modified to make a base case for comparative studies. A description of each existing test house is as follows:

TEST HOUSE ONE
Test House One is a single story bungalow, with a gross floor area of 98 square metres (1056 square feet) which was constructed in 1974.

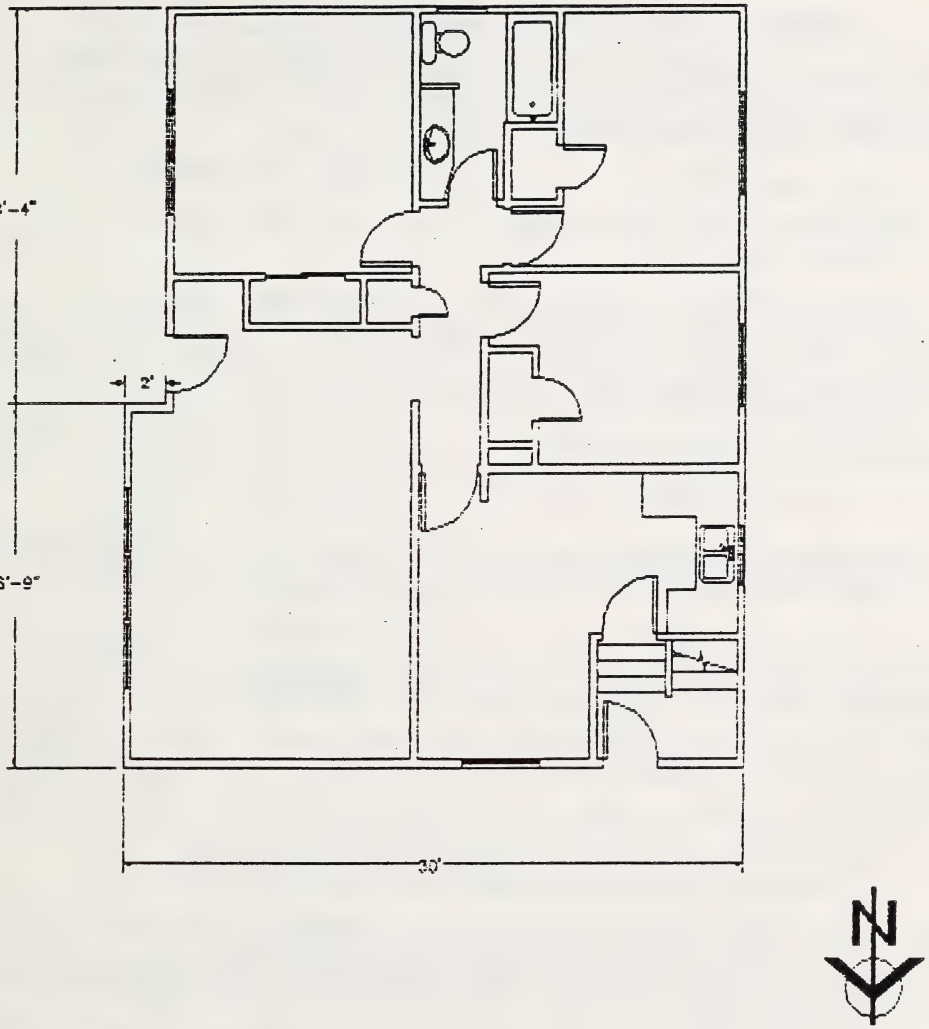
The basement walls are uninsulated. The main floor walls are 2 x 4 construction with glass fibre batt insulation, poly vapour barrier, gypsum board and a stucco finish on the exterior. The RSI value of the walls is 2.2 (R-12.6). The ceiling is insulated with 63.5mm (2.5 inches) of cellulose loose fill insulation with an RSI value of 1.7 (R-9.6). The main floor plan for Test House One is shown in Figure 3.1, on page 14. Energy bills for Test House One are listed in Appendix B. The results of the "As Is" simulation are listed in Appendix C. The simulated annual gas consumption is less than the actual consumption by 5.2%.

TEST HOUSE TWO
Test House Two is a single story bungalow, with a gross floor area of 94 square metres (1016 square feet), which was constructed in 1960.

The basement walls are partially insulated. The main floor walls are 2 x 4 construction with glass fibre batt insulation, a waxed paper vapour barrier, a gypsum interior and a stucco finish on the exterior. The RSI value of the walls is 2.2 (R-12.6). The ceiling is insulated with 178mm (7 inches) of glass fibre batt insulation with a RSI value of 4.4 (R-25). The main floor plan for Test House Two is shown in Figure 3.2, on page 15. Energy bills for Test House Two are listed in Appendix B. The results



drawing no. Fig. 3.1	TEST HOUSE No.1 MAIN FLR. PLAN	scale: N.T.S. date: OCT.17/86 drawn by: D.R. file no: 8634	SUNTON ENGINEERING LTD.



drawing no. Fig.3.2	TEST HOUSE No.2 MAIN FLR. PLAN	scale: N.T.S. date: OCT.17/86 drawn by: D.R. file no: 8634	SUNTON ENGINEERING LTD.

of the "As Is" simulation are listed in Appendix C. The simulated annual gas cost is less than the actual cost by 5.6%.

3.2.2 Computer Model of Base Building

The Hotcan computer model of Test House One was modified to reflect current construction norms. The following parameters are included in the base model:

- ceiling insulation	RSI 6	(R-34)
- basement wall insulation (above grade)	RSI 1.4	(R-8)
- basement wall insulation (first 0.6 m. (2 feet) below grade)	RSI 1.4	(R-8)
- above grade wall insulation	RSI 2.1	(R-12)
- double glazed windows		
- air infiltration rate	0.4 ACH	
- seasonal efficiency of gas fired appliances	65%	
- outside air quantity	0.5 ACH	
- base electric load	14kWh/day	

The inputs and outputs of the test house simulations and retrofit simulations are avaible from Alberta Municipal Affairs.

3.2.3 Analysis of Energy Conservation Opportunities

The base model was modified to simulate increased levels of insulation, air tightness, and seasonal efficiency. In this way, potential energy savings due to building envelope modifications can be assessed.

The following computer simulations were undertaken:

1. Base model except RSI 8.8 (R-50) in the ceiling
2. Base model except RSI 1.4 (R-8) full height of the basement wall
3. Base model except RSI 2.1 (R-12)full height of the basement wall
4. Base model except RSI 3.5 (R-20) walls
5. Base model except RSI 4.8 (R-27) walls
6. Base model except RSI 1.1 (R-6) basement floors
7. Base model except triple glazed windows
8. Base model except 0.1 air changes per hour infiltration

9. Base model except 78% seasonal efficiency furnace
10. Base model except 95% seasonal efficiency furnace
11. Base model except air to air heat recovery with 65% seasonal efficiency
12. Base model except RSI 8.8 (R-50) ceiling, RSI 2.1 (R-12) all basement walls, RSI 3.5 (R-20) walls, RSI 1.1 (R-6) basement floor, triple glazed windows, an infiltration rate of 0.1 air changes per hour, 78% furnace efficiency and 65% efficiency heat recovery

These computer simulations are aviaible from Alberta Municipal Affairs.

The results of the computer simulations are summarized in Table 3.1, on page 18. The annual savings are listed along with estimated implementation costs. The implementation costs are based on new construction as of November 1986 for the Edmonton area. A simple payback of ten years is deemed acceptable in this study because the value of the annual energy savings almost equals the mortgage interest cost to finance the incremental capital costs of the energy conservation measure.

Option One
The upgrade of the ceiling insulation from RSI 6 (R-34) to RSI 8.8 (R-50) has a simple payback of approximately 30 years.

Option Two
This option determined that the extension of RSI 1.4 (R-8) basement wall insulation to the floor has a simple payback of 3.8 years.

Option Three
This option indicates that a 3.3 year simple payback would result from installing RSI 2.1 (R-12) batt insulation for the full height of the basement walls instead of RSI 1.4 (R-8) batt.

Option Four
Installing RSI 3.5 (R-20) walls instead of RSI 2.1 (R-12) walls, indicates a 7 year simple payback. Two RSI 3.5 (R-20) walls were priced using local contractor prices. One RSI 3.5 (R-20) wall was 2x6 stud construction with glass fibre insulation. The second RSI 3.5 wall was 2x4 stud construction with glass fibre insulation and 38.1mm (1 1/2 inch) of rigid insulation. The cost of estimates for both wall systems were similar.

Option Five
Installing a 2x6 stud wall with glass fibre insulation and 38.1mm (1 1/2 inch) of rigid insulation, yielded a 10.5 year simple payback.

TABLE 3.1

RESULTS OF ANALYSES OF CONSERVATION OPPORTUNITIES

OPTIONS	CONSERVATION OPPORTUNITIES	GJ	ANNUAL COST FOR HEATING	SAVING AMOUNT	EXTRA CAPITAL COST	SIMPLE PAYBACK (YEARS)
	TEST HOUSE "AS IS"	119	$538.00			
	BASE BUILDING	107	$444.00	$0.00		
ONE	RSI 8.8 (R-50) CEILING	104	$432.00	$12.00	$369.60	30.8
TWO	RSI 1.41 (R-8) BASEMENT WALLS	102	$424.00	$20.00	$76.95	3.8
THREE	RSI 2.1 (R-12) BASEMENT WALLS	97	$400.00	$44.00	$144.96	3.3
FOUR	RSI 3.5 (R-20) WALLS	98	$407.00	$37.00	$259.71	7.0
FIVE	RSI 4.75 (R-27) WALLS	95	$393.00	$51.00	$534.31	10.5
SIX	RSI 1.08 (R-6) BASEMENT FLOOR	102	$424.00	$20.00	$528.00	26.4
SEVEN	TRIPLE GLAZED WINDOWS	105	$434.00	$10.00	$490.00	49.0
EIGHT	INFILTRATION RATE OF 0.1 ACH	95	$395.00	$49.00	$500.00	10.2
NINE	78% FURNACE EFFICIENCY	107	$370.00	$74.00	$753.00	10.2
TEN	95% FURNACE EFFICIENCY	107	$304.00	$140.00	$1,650.00	11.8
ELEVEN	HEAT RECOVERY 65% EFFICIENCY	81	$338.00	$106.00	$1,500.00	14.2
TWELVE	ALL CONSERVATION OPPORTUNITIES	42	$144.00	$288.00	$5,205.27	18.1

* all extra capital costs are based on prices prevailing in the Edmonton Area as of November 1986

Option Six
Installing 25.4mm (1 inch) of rigid insulation below the basement floor slab would yield a 26.4 year simple payback.

Option Seven
Installing triple glazed windows instead of double glazed windows would result in a 49 year simple payback.

Option Eight
Reducing the infiltration rate from 0.4 air changes per hour to 0.1 air changes per hour would yield a 10.2 year simple payback. In reality, tightening the building envelope to this degree would require intermittent mechanical ventilation which would probably offset the potential savings.

Options Nine and Ten
Analyses of the use of mid efficiency and high efficiency furnaces for the size of house analyzed, indicate that the mid efficiency furnace with a 10.2 year payback appears to make more sense economically than a high efficiency furnace with a 11.8 year simple payback.

Option Eleven
Heat recovery, with a seasonal efficiency of 65% was simulated. The base model annual energy consumption was reduced from 107GJ to 81GJ . This represents a saving of $106.00 with a 14.2 year simple payback.

Option Twelve
Finally, all conservation opportunities with the highest savings potential were applied to the base model. This analysis indicates that the annual cost of heating could possibly be reduced to $ 144.00 per year by implementing the following measures.

- install RSI 8.8 insulation in the ceiling
- install RSI 2.1 insulation in the basement walls
- install RSI 4.75 walls
- install RSI 1.08 under the basement floor slab
- install triple glazed windows
- reduce infiltration rate to 0.1 ACH
- install a mid (78%) efficiency furnace

add a heat recovery ventilator with 65% seasonal efficiency

This represents a simple payback of 18.1 years.

3.3 BACK DRAFTING

3.3.1 Introduction

The air requirements and the pressure differentials associated with various household appliances and devices were discussed in Chapter 2. If two or more of these devices are operating simultaneously, the air requirements are not necessarily the arithmetic sum of the devices. Hamilton and Gray[1] conclude "Two fans display interactional effects when operating simultaneously. Thus, their combined performance cannot be obtained by simple addition of their individual performances". The combined operation of household appliances and devices can cause downdrafting in atmospheric gas-fired appliances.

This section will outline the basic principles of gas vent systems, describe methods for testing for backdrafting, review a computer program which simulates a furnace/draft-diverter/vent system, and review the latest Alberta Building Code requirement for combustion air supplies in housing.

3.3.2 Principles of Gas Vent Systems

The products of combustion generated in a furnace must be removed from the building. Atmospheric gas-fired appliances use a system consisting of a draft diverter, gas vent, and rain cap to remove the products of combustion. This is shown schematically in figure 3.3.(on page 21)

Combustion air enters at the bottom of the furnace. This combustion air mixes with natural gas which burns in the heat exchanger to produce flue gasses.

Dilution air enters via the draft diverter. The dilution air cools the flue gasses. The resulting stack gasses travel through the gas vent driven by buoyancy effects. Gas friction at the gas vent walls and fittings subtract from the buoyancy effects.

ASHRAE[2] publishes a nomograph which facilitates the calculation of theoretical draft. This is a function of chimney gas temperature, chimney height, barometric pressure, and ambient air temperature. Table 6 of the same publication indicates that 300oF is a representative temperature for natural gas-fired heating appliances with a draft hood.

System flow losses must be calculated for the gas vent system being analyzed. These losses, subtracted from the theoretical draft calculated above to arrive at available draft in inches water column (which can be converted to Kilopascals by multiplying by 0.2487). If the available draft is greater than any negative pressure across the building envelope, the chimney will operate satisfactorily. For more information, the reader is encouraged to read chapter 27 of the 1983 ASHRAE Equipment Handbook.

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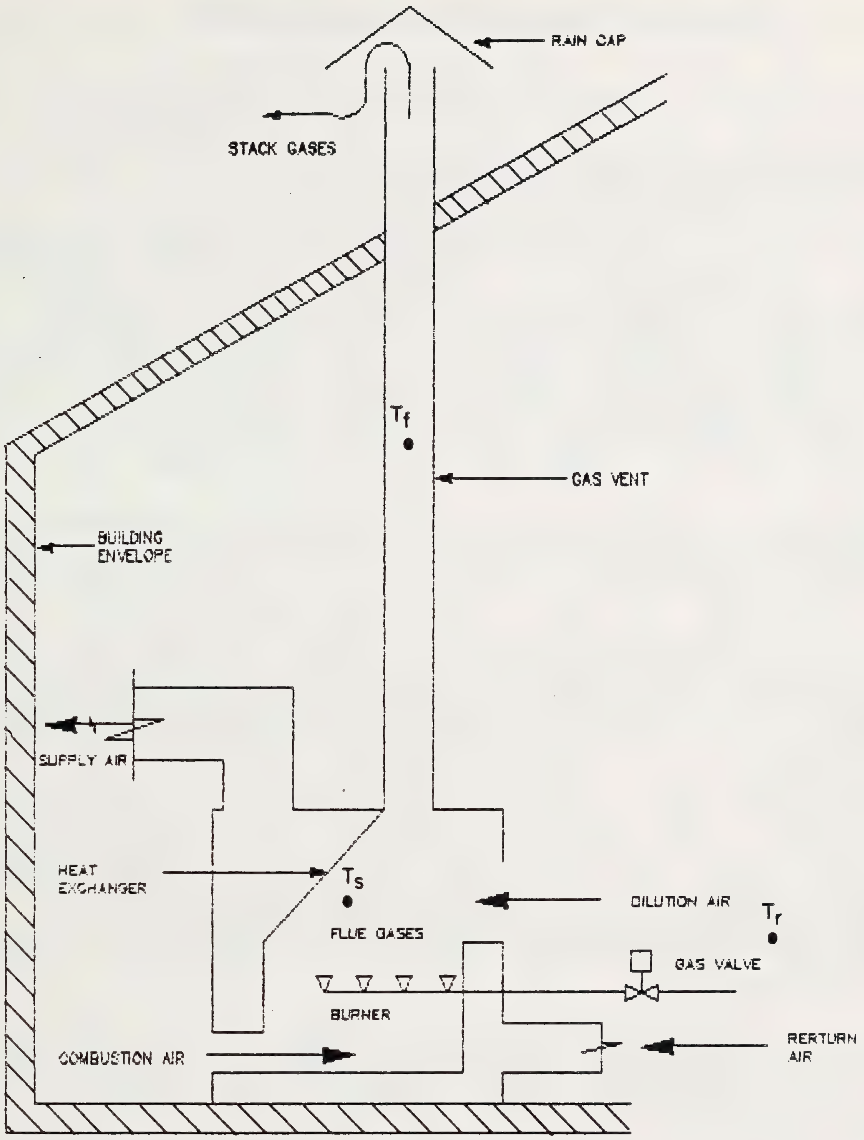
[1] Hamilton and Gray, "The Effect of Exhaust fans and Remedial Measures on House Depressurization"

[2] ASHRAE HANDBOOK, 1983, Equipment, 27.8 figure 5



SUNTON
ENGINEERING

GAS VENT SYSTEM SCHEMATIC

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Fig. 3.3

3.3.3 Testing For Backdrafting and Spillage

If two devices that require outside air are operating simultaneously, they will compete for the available outside air. Outside air is brought into the house through the combustion air duct, the outside air intake to the ventilation system, and through openings in the building envelope.

Prior to the trend towards airtight building envelopes, air infiltration was generally adequate to ensure that all outside air requirements were met. With the advent of airtight building envelopes, infiltration may no longer be adequate to supply sufficient outside air when several devices operating simultaneously and demand more outside air than the combustion air and outside air intakes can supply. In this case, the devices begin competing for the available outside air. The device capable of imposing the greatest pressure difference will prevail.

Atmospheric gas-fired devices rely on the buoyancy of hot exhaust gases to produce the pressure differential necessary to remove the products of combustion. The pressure differential is in the order of 7 Pa. An induced draft fan can be added to boost this by about 10 Pa (see Table 2.1 on page 7).

An examination of Table 2.1 shows that any fan powered device is capable of producing a larger pressure differential causing downdrafting. If the outside air requirements of several appliances operating simultaneously exceed the air supplied by the combustion air duct, fresh air duct, and infiltration, the balance of the outside air required will be brought in via the chimney of the naturally aspirating gas-fired appliance. This would result in the products of combustion of the gas-fired appliance spilling into the building through the draft diverter. This situation could result in carbon monoxide poisoning of the building occupants and long term exposure to products of combustion.

Severe backdrafting is easily detected by approaching the appliance in question and placing your hand near the draft hood or draft diverter. If hot gasses are spilling out, a serious problem exists.

A properly functioning atmospheric gas-fired appliance will induce 40% dilution air through the draft hood or draft diverter when the kitchen and bathroom exhaust fans are on, outdoor wind velocity is less than 2.2 m/s (5mph) and the indoor-outdoor temperature differential is less than 18oC (30oF). ASHRAE standard 62-1981[1] outlines a test for adequate combustion air which involves measuring the flue temperature (TF), the stack temperature (TS), and the room temperature (TR). If the stack temperature is greater than TS= (TF + 0.4TR)/1.4, backdrafting is probable.

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[1] ASHRAE STANDARD 62-1981

3.3.4 Standata 85-DI-017

The Building Standards Branch of Alberta Labour has published a bulletin that is intended to ensure adequate combustion air for atmospheric gas-fired appliances. Two methods of supplying combustion air and fresh air are outlined.

Method 1 requires a combined combustion air and fresh air duct. The size of this duct varies with the combined input ratings of the gas-fired appliance. It is important to realize that if two furnaces are installed, then two combined ducts are required. Method 1 also requires that the furnace run continuously to ensure adequate combustion air for the domestic hot water heater. A two speed fan motor is recommended.

Method 2 requires separate fresh air and combustion air ducts. The combustion air duct must be sized at 450m2/kw based on the combined input ratings of all atmospheric gas-fired appliances.

It is extremely important to understand that the duct sizes that are specified are only sufficient to provide combustion air. Air required by washroom exhaust fans, kitchen fans, wood stoves, fireplaces, etc. must be supplied separately. A copy of Standata 85-DI-017 is provided in Appendix D.

3.4 MOISTURE

3.4.1 Introduction

Excessive humidity levels can result in surface condensation and concealed condensation which can cause serious damage to residential buildings.

Concealed condensation results when moisture-laden air finds its way into building assemblies such as walls or roofs. The moisture laden air enters these assemblies through discontinuities in the air barrier. Moisture condenses from the air inside the walls or roofs. Moisture within these assemblies can reduce the effectiveness of the insulation, cause rotting of structural elements, and promote the growth of mould and mildew.

Surface condensation results when the temperature of a surface is less than the dew point temperature of the air in contact with the surface. Surface condensation often shows up as water on windows in the winter. This condensation is an indication that the humidity level in the building is excessive. Surface condensation can be used to help predict the onset of concealed condensation.

3.4.2 Graphical Analyses to Determine Permissible Relative Humidity Levels

Graphical analyses was used to predict surface condensation on single, double and triple glazing at various outside air temperatures.

R-values derived from ASHRAE 1985 Fundamentals Handbook[1] were plotted on the x-axis against outdoor air temperature on the y-axis for single, double, and triple glazing (see Figures 3.4, 3.5 and 3.6 (on pages 25 & 26). Lines connecting the indoor air temperature and various outdoor temperatures were constructed. These temperature gradient lines were used to determine the dew point temperature at the inner glass surface. The derived dew point temperatures for the three glass types are listed in Tables 3.2, 3.3 and 3.4 on page 27.

A psychrometric chart was used to determine the indoor air relative humidity at which surface condensation commences. These values are listed in Tables 3.2, 3.3 and 3.4 under the heading % Permissible RH.

3.4.3 Dehumidification Air Requirements

The 1985 monthly meteorological summaries for Edmonton were analyzed to determine a representative average relative humidity level for Edmonton. A 60% relative humidity level was chosen for the outside air value used in the subsequent analyses.

Outside air is used to remove moisture from the interior of a house and maintain an acceptable indoor relative humidity level. Relatively dry outside air is introduced into the house and this air absorbs moisture which is then exhausted to remove moisture from the interior of the house.

The dehumidifying capacity of outside air is a function of its dry bulb temperature and its moisture content. The quantity of outside air required to maintain an acceptable relative humidity level in the interior of a house is a function of the outside air dry bulb temperature, and the rate of moisture addition to the indoor air. The relationship between these values is equation 3, page 4.8 of the 1982 ASHRAE Applications Handbook.

The equation is $Q = \frac{wp/C4}{C5(W1-W0)}$

where

Q = quantity of air, 1/s (cfm)
C4 = time conversion to minutes

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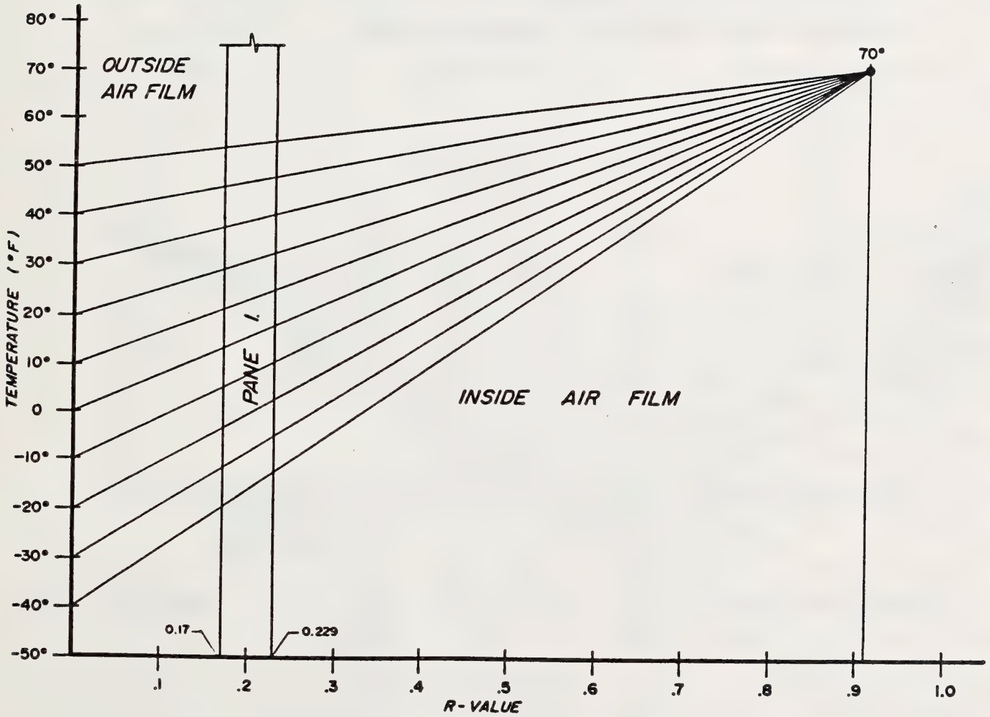
[1] ASHRAE 1985 FUNDAMENTALS HANDBOOK, Table 1 of Chapter 23 and Table 13 of Chapter 27

C5 = standard air density, 0.075 lb/cu.ft. (1.2041 kg/m3)
W0 = humidity ratio of outdoor air, lb/lb (kg/kg)
W1 = humidity ratio of indoor air, lb/lb (kg/kg)
wp = the evaporation of water, lb/hr (kg/s)

There is an error in the 1982 ASHRAE Applications Handbook. C4 is a time conversion to minutes rather than a time conversion to seconds.

A Canada Mortgage and Housing Corporation publication 1, quantifies moisture produced by a family of four. Twenty-three kilograms of moisture per day is considered representative. This translates to 0.95 kg (2.1 lb.) per hour. For this reason, the moisture addition was varied from 0.23 kg/hr (0.5 lb/hr) to 1.36 kg/hr (3.0 lb/hr) in increments of 0.23 kg/hr (0.5 lb/hr).



TEMPERATURE GRADIENT, SINGLE GLASS Fig. 3.4

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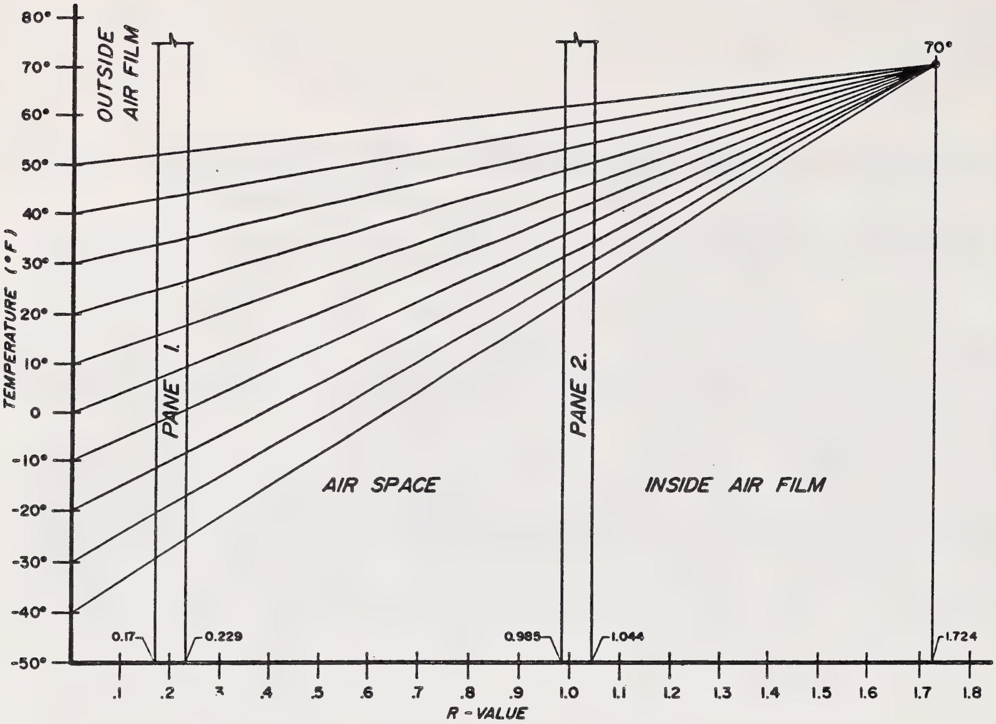
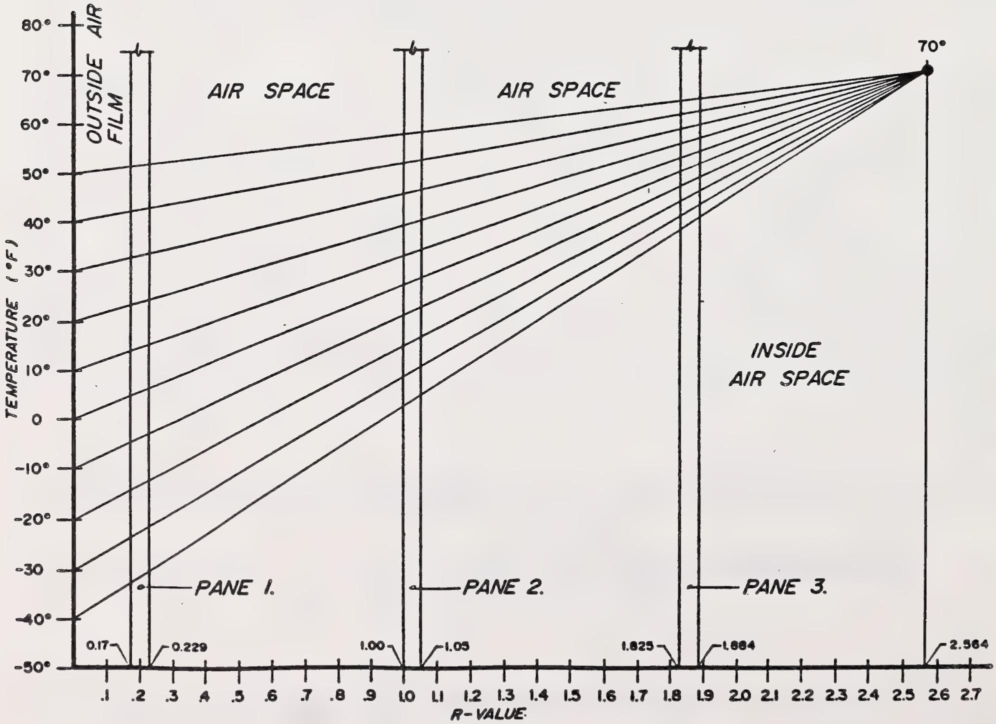
1 "Condensation in the Home: Where, Why and What to Do About It" Table 1, page 6.



TEMPERATURE GRADIENT, DOUBLE GLASS Fig. 3.5



TEMPERATURE GRADIENT, TRIPLE GLASS Fig. 3.6

TABLE 3.2
PERMISSIBLE RELATIVE HUMIDITIES FOR SINGLE GLAZING

oC (oF) Outside Temp.	oC (oF) Dew Point	% Permissible RH
-40 (-40)	-24 (-12)	1
-34 (-30)	-20 (- 4)	3
-29 (-20)	-16 (3)	5
-23 (-10)	-12 (11)	9
-18 (0)	-8 (18)	13
-12 (10)	-4 (25)	18
-7 (20)	1 (33)	25
-1 (30)	4 (40)	33
4 (40)	9 (48)	46
10 (50)	13 (55)	58

TABLE 3.3
PERMISSIBLE RELATIVE HUMIDITIES FOR DOUBLE GLAZING

oC (oF) Outside Temp.	oC (oF) Dew Point	% Permissible RH
-40 (-40)	- 3 (27)	20
-34 (-30)	- 1 (31)	22
-29 (-20)	2 (35)	27
-23 (-10)	3 (38)	30
-18 (0)	6 (43)	38
-12 (10)	8 (47)	44
-7 (20)	10 (50)	49
-1 (30)	12 (54)	56
4 (40)	14 (58)	66
10 (50)	17 (62)	76

TABLE 3.4
PERMISSIBLE RELATIVE HUMIDITIES FOR TRIPLE GLAZING

oC (oF) Outside Temp.	oC (oF) Dew Point	% Permissible RH
-40 (-40)	5 (41)	35
-34 (-30)	6 (43)	38
-29 (-20)	8 (46)	42
-23 (-10)	9 (48)	46
-18 (0)	11 (52)	53
-12 (10)	12 (54)	57
-7 (20)	14 (57)	63
-1 (30)	15 (59)	68
4 (40)	17 (62)	76
10 (50)	18 (64)	82

A computer program (see Appendix E) containing the psychrometric chart and equation 3 from ASHRAE were used to determine dehumidification air quantities required at various outdoor ambient temperatures and moisture addition rates to prevent surface condensation on single, double, and triple glass. Indoor temperature was assumed to be 21°C (70°F).

The results of the computer runs are listed in Tables 3.5, 3.6 and 3.7 on page 29. These results are displayed graphically in figures 3.7, 3.8, and 3.9 (on pages 30 and 31).

3.4.4 Annual Cost of Dehumidification Air

The dehumidification air computer program was used to calculate the amount of outside air required to prevent condensation on single, double, and triple glazed windows in Edmonton, Alberta. Normal monthly outdoor temperatures for Edmonton, provided by Atmospheric Environment services, were utilized. An average, of 60% relative humidity, was assumed.

The monthly energy required to heat the dehumidification air was determined using a modification of an equation from ASHRAE[1] Systems handbook. The modified equation is as follows:

$$A = (1.08)\ (CFM)\ (\Delta T) \times hrs/10^5$$

where A = sensible heat added to the dehumidification air (therms) each month
1.08 = a constant of proportionality derived from (60/13.33) (0.24 + 0.45) where $W = 0$
W = humidity ratio of the air in kg/kg (lb/lb)
CFM = cubic feet per minute of dehumidification air from the dehumidification air computer program
ΔT = the difference between the thermostat setpoint (70°F assumed) and the average monthly temperature
hrs = the number of hours in the month
10^5 = the conversion from Btu to therms

Monthly sensible heat requirements were calculated. These requirements were listed in Table 3.8 on page 32, in therms and gigajoules (GJ). (1GJ = 9.48 therms). The cost of heating the air is based on a representative unit price of $2.50/GJ. Heating plant efficiency was assumed to be 100%. A more accurate estimate of the cost could be obtained by dividing the cost estimates in Table 3.8 by the seasonal efficiency of the heating plant.

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[1] ASHRAE, 1980 Systems Handbook, Page 3.4 equation 1

TABLE 3.5

DEHUMIDIFICATION AIR REQUIREMENTS

SINGLE GLAZING

Moisture added		Outside Temp. -28.89C	(-20 F)	Outside Temp. -17.78C	(0 F)	Outside Temp. -6.67C	(20 F)	Outside Temp. 4.44C	(40 F)
kg/hr	lb/hr	l/s	cfm	l/s	cfm	l/s	cfm	l/s	cfm
0.23	0.5	68.9	(145.9)	35.5	(75.2)	21.0	(44.5)	13.0	(27.5)
0.45	1.0	137.7	(291.7)	71.0	(150.4)	42.0	(89.1)	26.0	(55.0)
0.68	1.5	206.5	(437.6)	106.5	(225.6)	63.1	(133.6)	38.9	(82.5)
0.91	2.0	275.4	(583.5)	142.0	(300.8)	84.1	(178.1)	51.9	(110.0)
1.14	2.5	344.2	(729.3)	177.5	(376.0)	105.1	(222.7)	64.9	(137.5)
1.36	3.0	413.1	(875.2)	213.0	(451.2)	126.1	(267.2)	77.9	(165.0)

These results are presented graphically in Figure 4.7

TABLE 3.6

DEHUMIDIFICATION AIR REQUIREMENTS

DOUBLE GLAZING

Moisture added		Outside Temp. -28.89C	(-20 F)	Outside Temp. -17.78C	(0 F)	Outside Temp. -6.67C	(20 F)	Outside Temp. 4.44C	(40 F)
kg/hr	lb/hr	l/s	cfm	l/s	cfm	l/s	cfm	l/s	cfm
0.23	0.5	12.6	(26.7)	9.8	(20.7)	8.4	(17.8)	7.3	(15.4)
0.45	1.0	25.[illegible]	(53.3)	19.5	(41.4)	16.8	(35.6)	14.6	(30.9)
0.68	1.5	37.8	(80.0)	29.3	(62.1)	25.2	(53.3)	21.9	(46.3)
0.91	2.0	50.4	(106.7)	39.1	(82.8)	33.6	(71.1)	29.1	(61.7)
1.14	2.5	62.9	(133.3)	48.9	(103.5)	42.0	(88.9)	36.4	(77.2)
1.36	3.0	75.5	(160.0)	58.7	(124.3)	50.4	(106.7)	43.7	(92.6)

These results are presented graphically in Figure 4.8

TABLE 3.7

DEHUMIDIFICATION AIR REQUIREMENTS

TRIPLE GLAZING

Moisture added		Outside Temp. -28.89C	(-20 F)	Outside Temp. -17.78C	(0 F)	Outside Temp. -6.67C	(20 F)	Outside Temp. 4.44C	(40 F)
kg/hr	lb/hr	l/s	cfm	l/s	cfm	l/s	cfm	l/s	cfm
0.23	0.5	8.1	(17.1)	6.8	(14.4)	6.2	(13.1)	5.9	(12.6)
0.45	1.0	18.1	(34.1)	13.6	(28.8)	12.4	(26.3)	11.9	(25.3)
0.68	1.5	24.2	(51.2)	20.4	(43.2)	18.6	(39.4)	17.9	(37.9)
0.91	2.0	32.2	(68.3)	27.2	(57.6)	24.8	(52.5)	23.9	(50.6)
1.14	2.5	40.2	(85.3)	34.0	(72.0)	31.0	(65.7)	29.8	(63.2)
1.36	3.0	48.3	(102.4)	40.7	(86.3)	37.2	(78.8)	35.8	(75.8)

These results are presented graphically in Figure 4.9

Fig. 3.7 SINGLE GLAZING

DEHUMIDIFICATION AIR

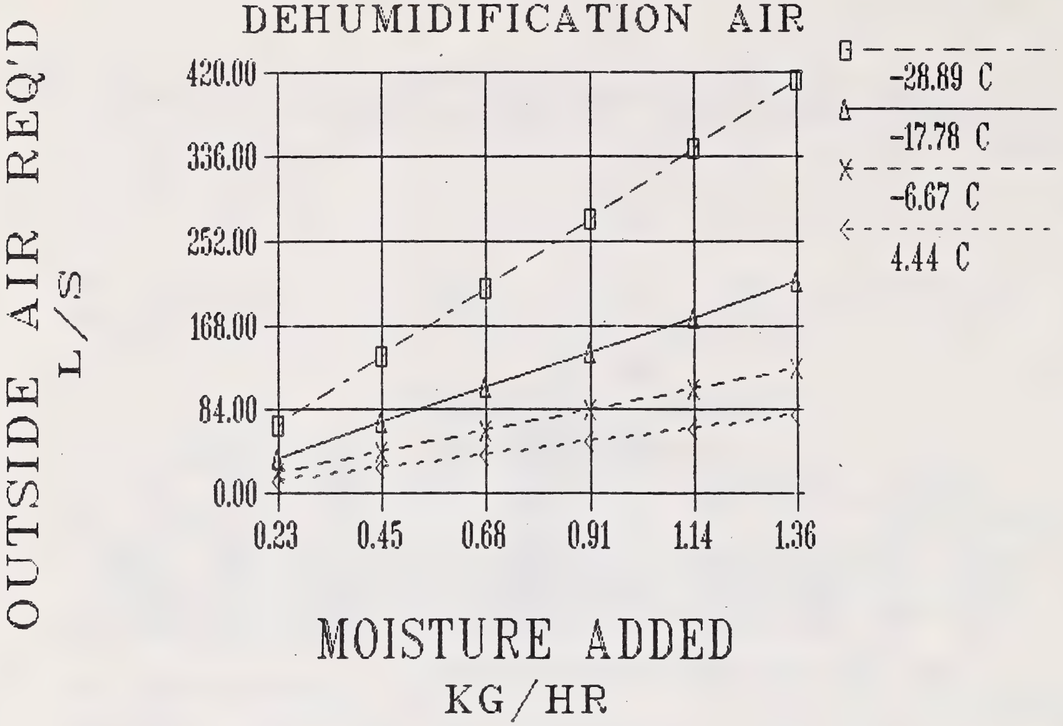

Fig. 3.8 DOUBLE GLAZING

DEHUMIDIFICATION AIR

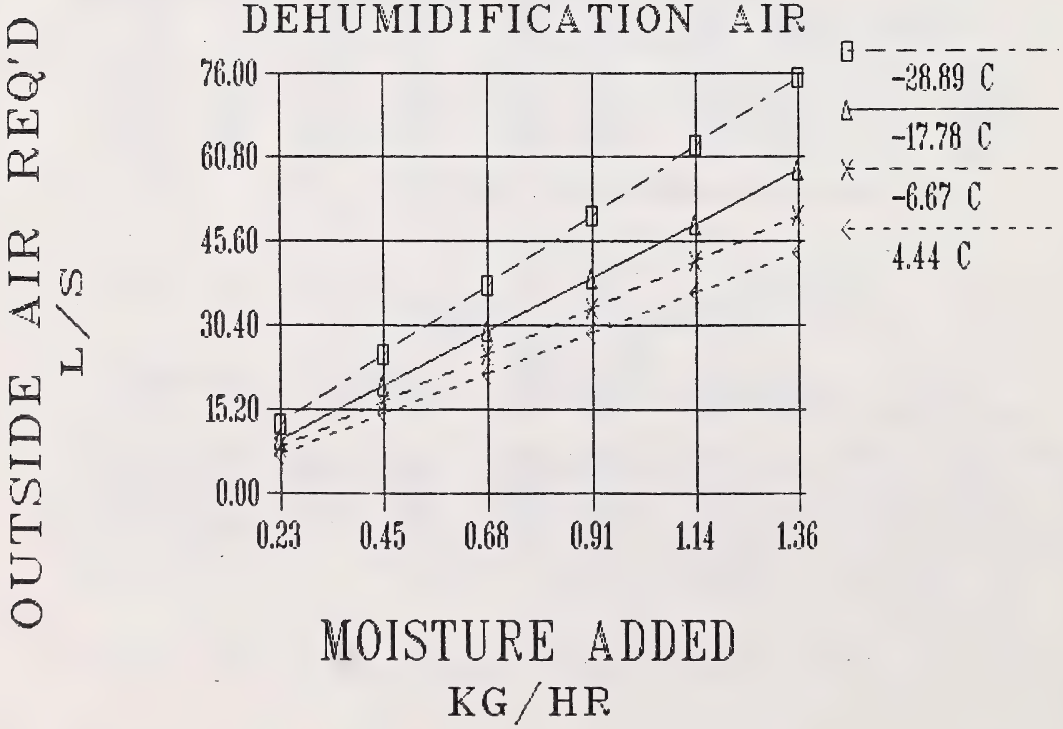

Fig. 3.9 TRIPLE GLAZING

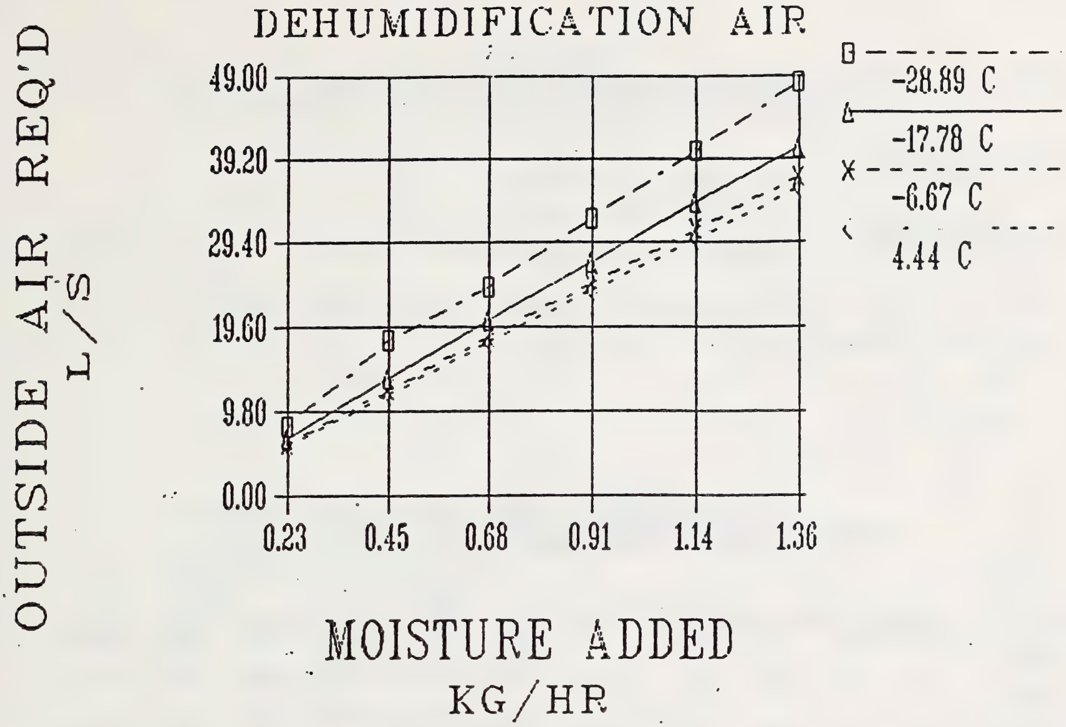

Table 3.9, on page 33, summarizes the cost to dehumidify air with an evaporation rate of 1, 2 and 3 pound per hour for single, double, and triple glazing. The numbers for 2 and 3 pounds per hour were derived by multiplying the totals in Table 3.8 by 2 and 3 respectively. Seasonal heating plant efficiency is not accounted for in Table 3.9 on page 33. Dividing the costs outlined in Table 3.9 by the seasonal efficiency of the heating plant will provide a reasonable estimate.

3.4.5 Dehumidification Air Changes Necessary to Prevent Condensation in Test House One

The volume of Test House One is[1] approximately 478 cubic meters (16,891 cubic feet). One air change per hour (ACH) is equal to 133 litres per second (282 cubic feet per minute). A. T. Hansen[2] suggests that an average family of four generates between seven and twelve litres of moisture per day with a maximum of twenty three litres per day. This converts to 0.29 kilograms per hour (0.64 lb/hour) to 0.55 kilograms per hour (1.1 lb/hour) with a maximum of 0.95 kilograms per hour (2.1 lb/hour). These moisture generation rates require the following peak dehumidification air change rates in January to prevent surface condensation on glass:

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[1] See Section 3.5 of this report, page 33.

[2] A.T. Hansen, "Moisture Problems in Houses"

Single Glazed
0.31 ACH to 0.53 ACH with a maximum of 1.02 ACH

Double Glazed
0.09 ACH to 0.16 ACH with a maximum of 0.3 ACH

Triple Glazed
0.002 ACH to 0.10 ACH with a maximum of 0.2 ACH

It is clear that dehumidification air requirements decrease with the number of layers of glass.

TABLE 3.8

DEHUMIDIFICATION AIR REQUIRED TO PREVENT CONDENSATION ON GLAZING PER POUND OF MOISTURE ADDED TO THE SPACE PER HOUR

	Normal Temperature		(CFM) Dehumidification Air			therms (GJ) Energy			($) Cost		
month	C	F	single glass	dbl. glass	trpl. glass	single glass	dbl. glass	trpl. glass	single glass	dbl. glass	trpl. glass
January	-15.0	5.0	136.6	40.3	26.6	71.34 (7.52)	21.05 (2.22)	13.89 (1.47)	18.81	5.55	3.66
February	-9.6	14.7	103.0	36.7	26.4	41.34 (4.36)	14.73 (1.55)	10.59 (1.12)	10.90	3.88	2.79
March	-5.0	23.0	80.1	33.2	25.9	30.25 (3.19)	12.54 (1.32)	9.78 (1.03)	7.98	3.31	2.58
April	4.2	39.6	54.3	28.2	23.5	12.84 (1.35)	6.67 (0.70)	5.55 (0.59)	3.39	1.76	1.46
May	11.3	52.3	44.2	27.1	25.6	6.29 (0.66)	3.85 (0.41)	3.64 (0.38)	1.66	1.03	0.96
June	15.1	59.2	38.1	30.6	27.0	3.20 (0.34)	2.57 (0.27)	2.27 (0.24)	0.84	0.68	0.60
July	17.4	63.3	37.4	30.8	28.2	2.01 (0.21)	1.66 (0.17)	1.52 (0.16)	0.53	0.44	0.40
August	16.2	61.2	39.2	29.3	27.5	2.77 (0.29)	2.07 (0.22)	1.94 (0.21)	0.73	0.55	0.51
September	11.0	51.8	44.8	31.3	24.6	6.34 (0.67)	4.43 (0.47)	3.48 (0.37)	1.67	1.17	0.92
October	5.8	42.4	54.8	30.1	25.2	12.15 (1.28)	6.68 (0.70)	5.59 (0.59)	3.20	1.76	1.47
November	-3.7	25.3	80.	34.0	24.1	27.81 (2.93)	11.82 (1.25)	8.38 (0.88)	7.33	3.12	2.21
December	-10.4	13.3	107.4	36.3	26.2	48.93 (5.16)	16.54 (1.74)	11.94 (1.26)	12.90	4.36	3.15
	Totals					265.27 (27.96)	104.61 (11.02)	78.57 (8.30)	69.94	27.61	20.71

TABLE 3.9
COST TO HEAT SUFFICIENT DEHUMIDIFICATION AIR TO PREVENT CONDENSATION ON GLASS IN EDMONTON

Evaporation To Space		Annual Cost to Heat Dehumidification Air ($)		
lb/hr	kg/hr	single glass	double glass	triple glass
1	0.45	$ 69.94	$ 27.61	$ 20.71
2	0.91	$ 139.88	$ 55.22	$ 41.42
3	1.36	$ 209.82	$ 82.83	$ 62.13

3.5 NATURAL AND FORCED VENTILATION RATES

3.5.1 Natural Ventilation

Natural Ventilation rates can be estimated using the following equation[1] :
$Iws = 4.5 C (A/V)$

where

Iws = air infiltration due to the combined action of wind and effect in air changes per hour in winter

C = flow coefficient, L/(s.m2.Pa)

A = surface area of the building envelope above grade m2

V = building volume including basement, m3

Table 1 of Shaw's publication lists values for the flow coefficient C. The averages of the average ratings for the three types of buildings were calculated. For standard construction, a value of 0.2 resulted. For low energy construction, a value of 0.1 was calculated.

Test House One has a floor area of 98 m2. The volume of the house, including basement, is 454m3. The above grade surface area is 214m2. The house has a kitchen, a bathroom, 3 bedrooms, a living room, a dining room and three rooms in the basement.

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[1] Shaw, C.Y., "Methods for Estimating Air Change Rates and Sizing Mechanical Ventilation Systems for Houses"

Using the values previously calculated for C, the parameters of Test House One, and Shaw's equation, we arrive at the following natural ventilation rates:

For standard construction Iws = 0.42 AC/hr
For airtight construction Iws = 0.21 AC/hr

The Department of Mechanical Engineering of the University of Alberta has been investigating natural air infiltration rates in housing. The unoccupied test houses at Ellerslie were used as laboratories. Appendix F summarizes data gathered in 1984. The test houses have about one-half of the floor area and the same flue area as a typical bungalow. D.J. Wilson, of the U of A, suggested that the values listed in Appendix C are approximately one-third less than infiltration rates for unoccupied full sized houses. Mr. Wilson also suggested that occupant behavior tends to increase infiltration rates by about 0.2 ACH.

Appendix F lists data for 5 test modules built using different construction materials and techniques. The envelope tightness ranges from good "standard" construction to "airtight" quality construction.

Applying Dr. Wilson's correction factor to the January infiltration figures in Appendix F, natural ventilation rates of 0.14 ACH for module 3 to 0.62 ACH for module 2 are predicted.

The numbers calculated using Shaw's equation fall within the corrected values observed by the U of A researchers.

3.5.2 Forced Ventilation Rates

Table 3.3 of ASHRAE Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality"[1] requires 5 l/s per room of outdoor air plus 50 l/s for kitchens and 25 l/s for bathrooms. The kitchen and bathroom requirements are on an intermittent use basis. These requirements applied to Test House One to quantify natural ventilation rates, results in an outside air quantity requirement of 105 l/s. This translates to 0.79 ACH for Test House One. This outside air rate can be broken down into a requirement of 0.23 ACH continuous and 0.56 ACH intermittent. Comparing these requirements to the natural ventilation rates calculated using Shaw's equation and to the rates observed by the U of A researchers we can draw the following conclusions:

- Natural ventilation rates should be adequate to provide the continuous ventilation rates required by ASHRAE in "leaky" houses with kitchen and washroom fans off.

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[1] ASHRAE 62-1981

- Natural ventilation rates may not be adequate to provide peak ventilation rates required by AHRAE in "leaky" or "airtight" houses.
- Natural ventilation rates cannot be relied on to provide the continuous or intermittent ventilation rates required by ASHRAE in "airtight" houses.

3.6 CONCLUSIONS

3.6.1 Backdrafting

Backdrafting occurs when the outside air requirements of several appliances operating simultaneously exceed the air supplied by the combustion air duct, the fresh air duct and infiltration.

ASHRAE Standard 62-1981 outlines a simple test for backdrafting based on a calculation involving stack temperature, flue temperature, and room temperature.

Standata 85-DI-01 outlines two methods of sizing combustion air ducts. Unfortunately, these requirements cannot guarantee that backdrafting will not occur in an airtight house, because air introduced via the combustion air ducts may provide replacement air for exhaust fans rather than being used for combustion air.

3.6.2 Moisture

Moisture problems can be characterized as surface condensation and concealed condensation. Surface condensation occurs because of excessive moisture generation rates within a building and/or insufficient dehumidification air. Surface condensation is most evident on windows or uninsulated walls. Increasing the number of glazings will allow higher levels of relative humidity without condensation on windows. In addition, the dehumidification air requirements (and heating cost) can be reduced by increasing the number of glazings.

Concealed condensation can result from any combination of excessive moisture generation, positive pressures within the building, and discontinuities in the air/vapour barrier.

3.6.3 Natural and Forced Ventilation Rates

Natural ventilation rates due to wind and stack effects can be quantified using Shaw's[1] equation. Results calculated using this equation fall within corrected values observed by U of A researchers.

Houses built using standard construction methods should be leaky enough to provide the continuous ventilation rates required by ASHRAE. Peak ventilation rates required by ASHRAE (using kitchen and washroom exhaust fans) may result in a negative pressure inside the house with respect to outdoors. Natural ventilation rates in airtight houses cannot be relied upon to provide continuous or intermittent ventilation rates required by ASHRAE.

3.6.4 Payback of Energy Conservation Measures

Ten years or less is considered an acceptable simple payback. Upgrading ceiling insulation from RSI 6 (R-34) to RSI 8.8 (R-50) is not cost effective.

RSI 2.1 (R-12) batt insulation for the full height of the basement walls has an acceptable payback. RSI 3.5 (R-20) stud walls have an acceptable payback compared with RSI 2.1 (R-12) stud walls. RSI 4.8 (R-27) walls do not have an acceptable payback compared with RSI 3.5 (R-20) walls. Installing 25.4 mm (1 inch) of rigid insulation below the basement floor slab does not yield an acceptable simple payback.

Installing triple glazed windows in lieu of double glazed windows does not yield an acceptable payback.

Airtight building envelopes yield a marginal payback compared with standard construction techniques.

The extra cost associated with a mid-efficiency furnace is acceptable, while the cost for a high efficiency furnaces is only marginally acceptable.

Heat recovery ventilators are not economically viable considering present ASHRAE ventilation requirements.

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[1] Shaw, C.Y. "Methods for Estimating Air Change Rates and Sizing Mechanical Ventilation Systems for Houses"

4.0 DESIGN OF HEATING AND VENTILATING SYSTEM FOR HOUSING

4.1 INTRODUCTION

The previous chapters of this report demonstrate that natural ventilation may not be adequate to provide adequate outside air for dehumidification, pollution control, or to prevent backdrafting from atmospheric gas-fired appliances. These problems tend to be more severe in new "airtight" houses than they are in older, leakier houses. The design options available for new houses are more varied than they are for retrofits of older homes. The following section lists the design criteria for low infiltration housing.

4.2 MECHANICAL SYSTEM DESIGN CRITERIA

Atmospheric natural gas fired appliances cannot be allowed to backdraft. In retrofits, where the building envelope is tightened, induced draft fans, operated by temperature switches near the draft hoods or diverters, would prevent backdrafting. In new houses, forced draft or atmospherically uncoupled appliances should be installed.

The mechanical system must be able to provide sufficient outside air to control the levels of humidity and air pollutants inside the building to acceptable levels.

Maintaining a slight negative pressure within the building with respect to outdoors would prevent moisture from being forced into the building envelope, causing concealed condensation. The negative pressure must not be large enough to cause backdrafting of gas-fired appliances or fireplaces.

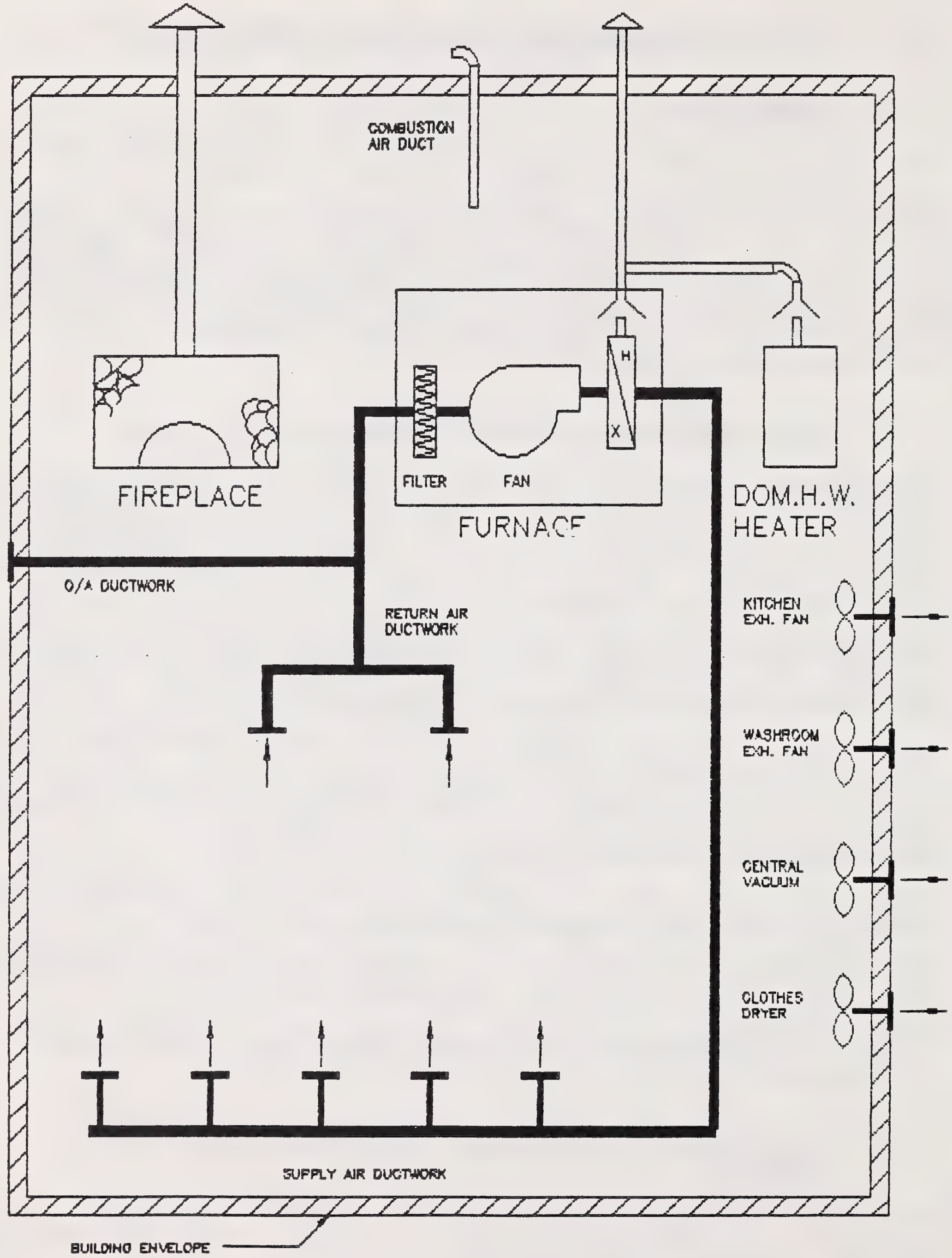
Fireplaces should be atmospherically uncoupled from the house using fan doors and dedicated combustion air supply.

The mechanical system must be capable of ensuring even heat distribution and ventilation throughout the house.

Finally, the mechanical system must be capable of satisfying all of the above criteria in a cost effective manner.

4.3 PRINCIPLES OF HEATING AND VENTILATING SYSTEMS FOR HOUSING

A typical house is equipped with a furnace, a domestic water heater, a kitchen exhaust fan, a clothes dryer and washroom exhaust fan(s). It may also be equipped with a fireplace, and sometimes a central vacuum system and/or a heat recovery ventilator (HRV). These components are shown schematically in Figure 4.1, on page 38.



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SCHEMATIC OF TYPICAL H & V
SYSTEM FOR HOUSING

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Fig 4.1

The furnace typically consists of a flat filter section, a forward curved centrifugal fan and a heat exchanger section. Supply air and return air ductwork are connected to the furnace. An outside air duct, typically about six inches in diameter is usually connected into the return air ductwork. This duct is supposed to replace air removed from the house by fans and appliances.

Ventilating systems for housing can be subdivided into two categories, namely balanced systems and negative pressure systems. Balanced systems attempt to maintain the same pressure within the building as the outside ambient pressure. To do this, air exhausted from the house is replaced by an equal quantity of air from outside. Negative pressure systems rely on outside air infiltration due to a pressure differential between the interior of the house and outdoors. The relative merits of each type of system are discussed later in this chapter.

Fireplaces compete with atmospheric gas fired appliances for combustion air. When the fireplace is burning quickly, it will downdraft atmospheric gas fired appliances if the building envelope is too "tight". When the fireplace is smouldering, the atmospheric gas fired appliances in combustion with other air exhausts like kitchen fans or clothes dryers may cause downdrafting in the fireplace.

The recommended solution to these problems is to uncouple the supply of combustion and make-up air for the fireplace from the house. This can be accomplished by equipping the fireplace with tight fitting tempered glass doors and a combustion air duct leading from the firebox to the outdoors.

A similar situation can occur with atmospheric natural gas fired appliances competing for make-up air with other air exhausting devices such as fans, dryers, central vacuum systems etc.

Clothes dryers discharge moisture and lint laden air. It is desirable to terminate the discharge duct from the clothes dryer outdoors. This will prevent an excessive moisture build-up inside the house.

Central vacuum systems are capable of developing a high static pressure. If the building is relatively airtight, backdrafting problems may result if the vacuum system discharges outdoors. It is recommended that the central vacuum system discharge indoors (into the basement for example).

4.4 BALANCED VENTILATION SYSTEM

4.4.1 Introduction

A balanced heating and ventilating system would vary the quantity of outside air introduced into a house to replace air removed by exhaust fans and appliances.

4.4.2 Economizer System

An economizer system could be added to a standard furnace system to accomplish this. An economizer system is shown schematically in Figure 4.2, on page 41. This system differs from a standard furnace system in that outside air and exhaust air ducts, sized to handle the entire fan volume, are provided. In addition, outside air, return air and exhaust air modulating dampers are provided.

The modulating dampers would be controlled by a differential pressure controller.

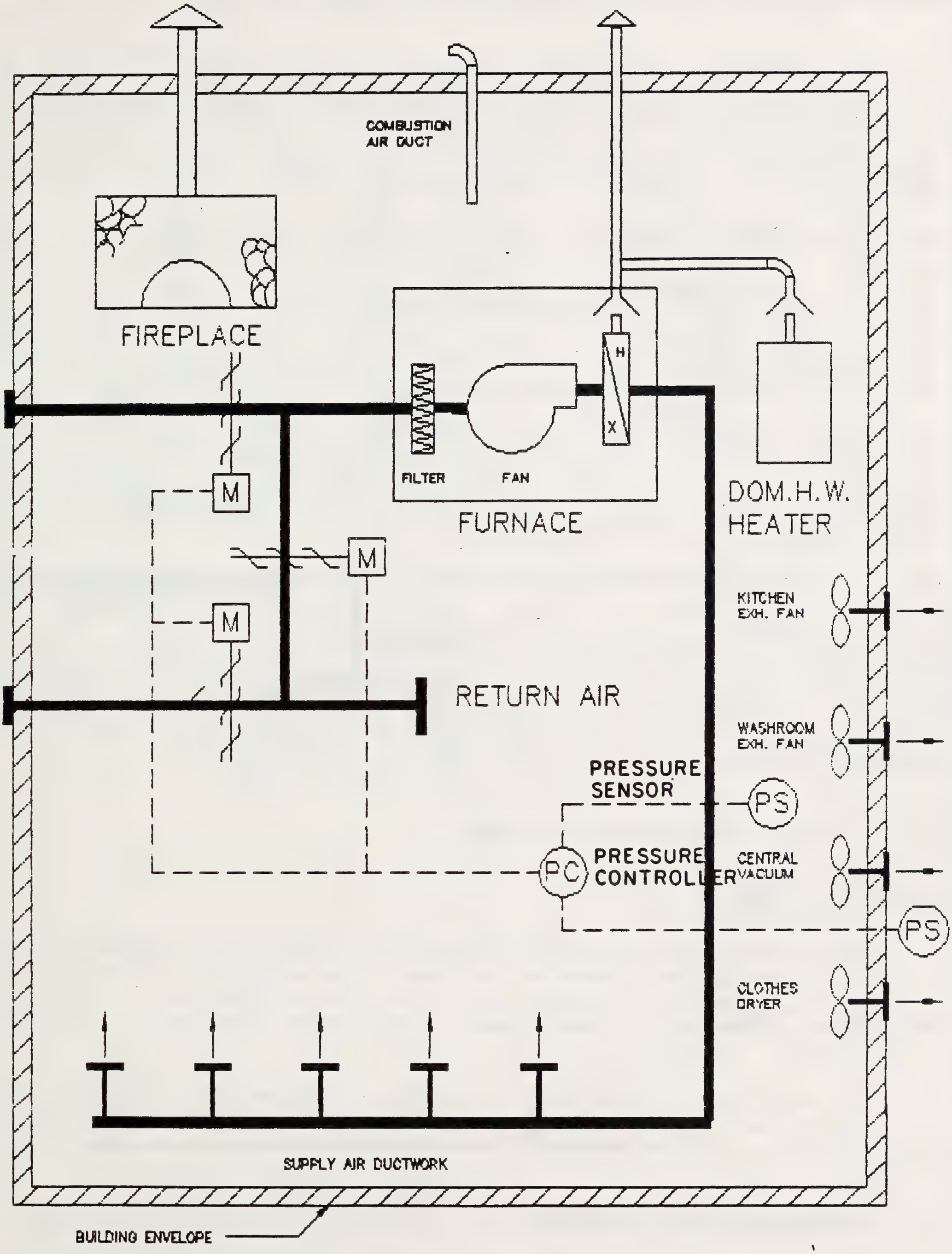
A balanced heating and ventilating system would prevent downdrafting in atmospheric gas fired appliances. The economizer would allow for "free cooling" in the spring and fall. Free cooling would increase the outside air quantity to satisfy the house thermostat setpoint if the outside air temperature is less than the thermostat setpoint.

An economizer could cause problems in cold weather if large exhaust volumes were initiated. In this case, the mixed air temperature could be low enough to cause corrosion of the furnace heat exchanger. To prevent this, either outside air preheat and/or an aluminized or stainless steel heat exchanger would be required.

A cost effective bolt-on economizer for the housing market is not yet available. A Lennox bolt-on economizer package not including differential pressure control costs approximately $ 1,500.00. Further research into this subject is recommended.

4.4.3 Heat Recovery Ventilators

A second type of balanced system would use a heat recovery ventilator (HRV). This system requires the outside air and exhaust air ductwork to be routed in such a manner that they run adjacent to each other. This additional ductwork not required in a house without a heat recovery ventilator could be expensive. The heat recovery ventilator consists of a supply fan, an exhaust fan, a heat exchanger grid, and the associated controls.



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ECONOMISER SYSTEM

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Fig 4.2

A heat recovery ventilator system is balanced at the time of installation. Clothes dryers, kitchen range hoods, or central vacuum system cannot be incorporated into a HRV system because of the contaminants (eg. lint, grease, or dust) associated with them. If these devices are vented to outdoors, they will throw a HRV system out of balance when operated.

The difference between implied ASHRAE requirements for the typical bungalow previously defined (0.79 ACH) and the winter natural ventilation rate for the typical airtight house (0.21 ACH) is 0.58 ACH. Assuming the activities of occupants increases the natural ventilation rate by 0.2 ACH, the mechanical ventilation system should be capable of providing at least 0.38 ACH. This translates to approximately 48 l/s (100 CFM).

Assuming a seasonal efficiency of 60% for an atmospheric natural gas fired furnace, 48 l/s of outside air would require approximately 64 GJ per year of natural gas in Edmonton, Alberta. At $2.75 GJ, the value of this outside air heat is approximately $ 176/year.

The installed cost of an air to air heat exchanger is in the order of $1,500. If the device was 100% efficient at recovering heat, the simple payback would be 8.5 years. Using a more realistic seasonal efficiency of 65%, the saving would be approximately $115/year, yielding a simple payback of about 13 years. Economically, it would make more sense to burn natural gas than it would to recover heat in a residential application using heat recovery ventilators on the market today.

4.5 NEGATIVE PRESSURE SYSTEMS

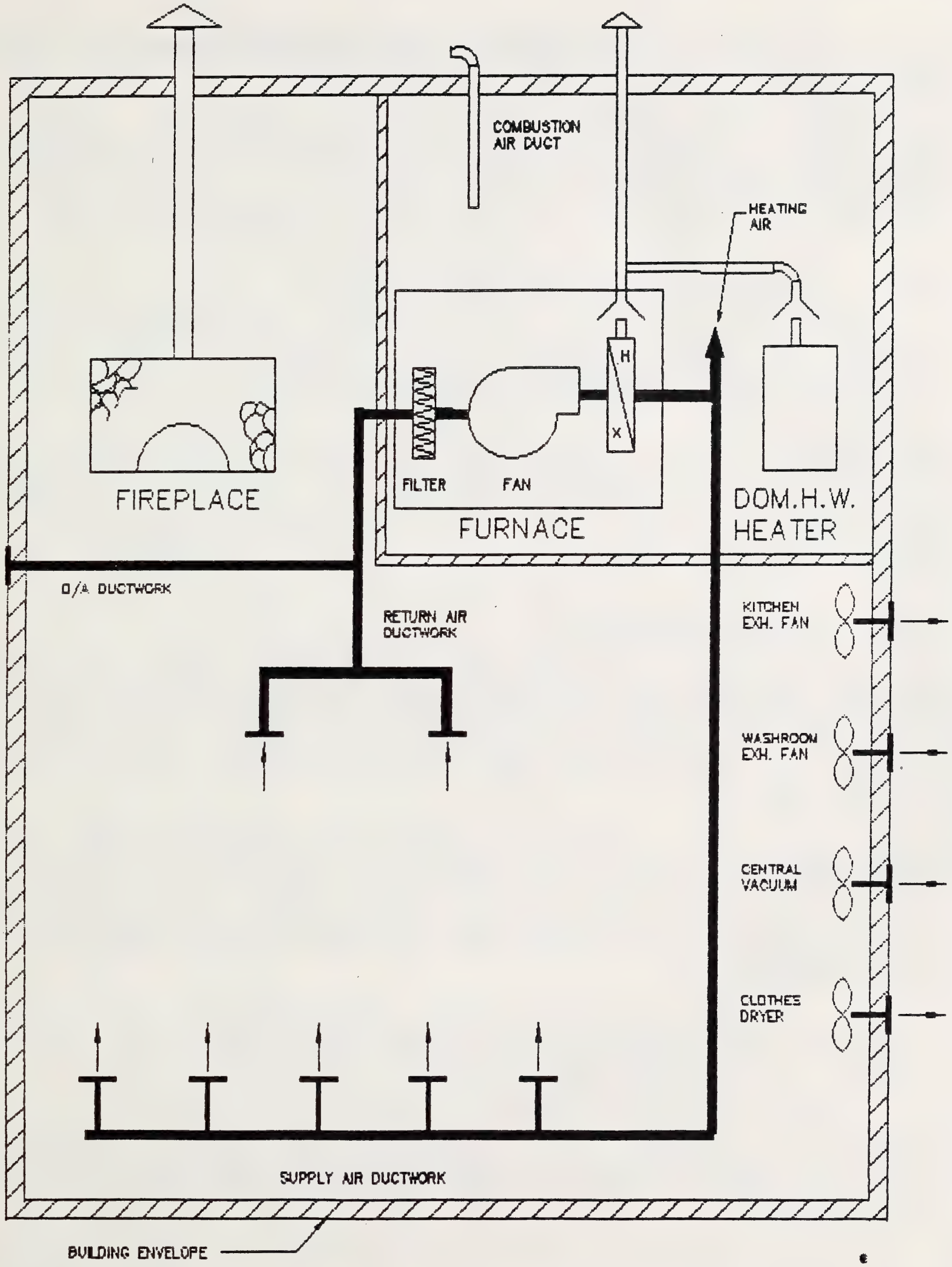
4.5.1 Introduction

A second way of approaching mechanical systems for housing is to accept a negative pressure across the building envelope. A negative pressure system has the advantage of preventing moisture laden air from being driven into the wall and roof assemblies.

If this approach is adopted, a means of preventing backdrafting in gas fired appliances must be provided. Several methods of accomplishing this are described below.

4.5.2 Sealed Furnace Room

One solution would be to enclose atmospheric gas fired appliances in a separate sealed room. Combustion air would be supplied to the room. This is shown schematically in Figure 4.3, on page 43. A means of heating the room would have to be provided to prevent freezing the domestic hot water heater. If heating air is supplied from the furnace system, building codes



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SEALED FURNACE ROOM

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Fig 4.3

will not allow it to be returned via the return air duct. The heating air would be relieved via the combustion air duct. This represents an unnecessary energy waste.

The cost of enclosing the gas fired appliances in a separate room would be approximately $ 500 based on 10m (30 feet) of 2.4m (8 feet) of wall.

4.5.3 Atmospherically Uncoupled Appliances

A second solution would be to install appliances that have outdoor air ducted directly to the appliance and discharge combustion products directly to outdoors without a draft diverter. This is shown schematically on Figure 4.4 on page 46.

An example of a direct vent furnace is the Lennox Pulse Furnace. This furnace would cost approximately $1,000 more than an atmospheric furnace. An example of a direct vent domestic water heater is a Model SSV-40-NDS4 manufactured by State Industries Inc.

4.5.4 Induced Draft Fan

A third solution involves adding an induced draft fan on the B-vent, serving both the furnace and the water heater. This fan would be activated by a signal from one of two temperature switches located near the draft diverters of the furnace and the domestic hot water heater. This is shown schematically in Figure 4.5, on page 47.

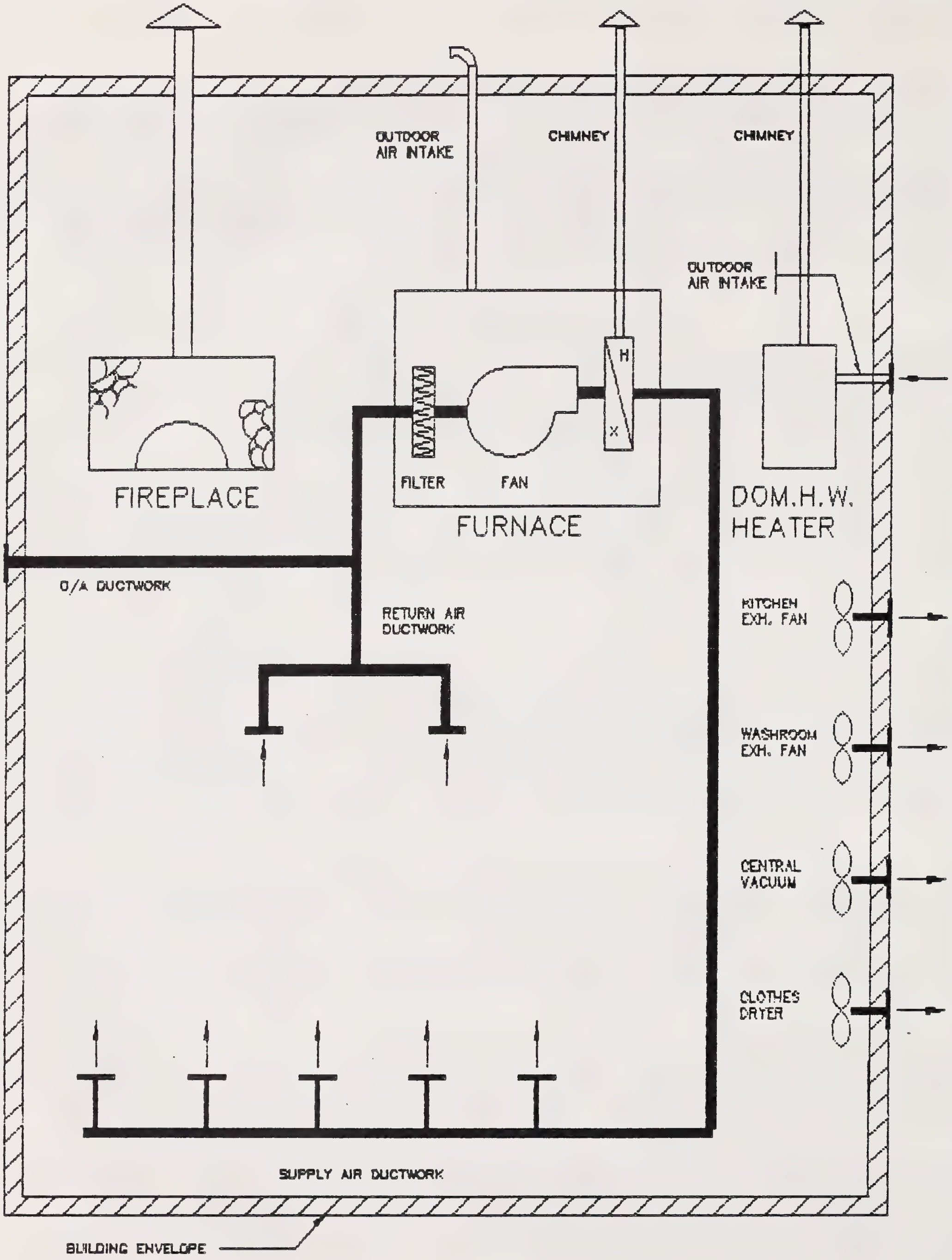
This solution was studied by Scandia Consultants Limited. They used Thermodisc 10H series temperature switches located at the draft diverter openings, to initiate an induced draft fan in the event of spillage. The fan used was the model DI-1 manufactured by the Field Control company. This system could be installed for approximately $400.

On new construction, induced draft appliances could be installed directly. An example of an induced draft gas fired hot water heater is the Rheem Model PV40-36M. The price of this unit is the same as the State Industries direct vent water heater.

Examples of induced draft furnaces are the Airco Turbo and ICG Ultimate models. These are mid efficiency furnaces which cost between $ 500 and $ 750, more than a standard atmospheric gas fired furnace.

4.6 DUCT SYSTEM DESIGN CONSIDERATIONS

Duct systems can be sized to reduce the friction losses through them. Increasing duct sizes will increase their installed cost while reducing the fan energy required to move air through them. Each installation can be analyzed to minimize the life cycle cost. Further information is available in ASHRAE or Sheet Metal and Air Conditioning Contractors National Association manuals.



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ATMOSPHERICALLY UNCOUPLED APPLIANCES

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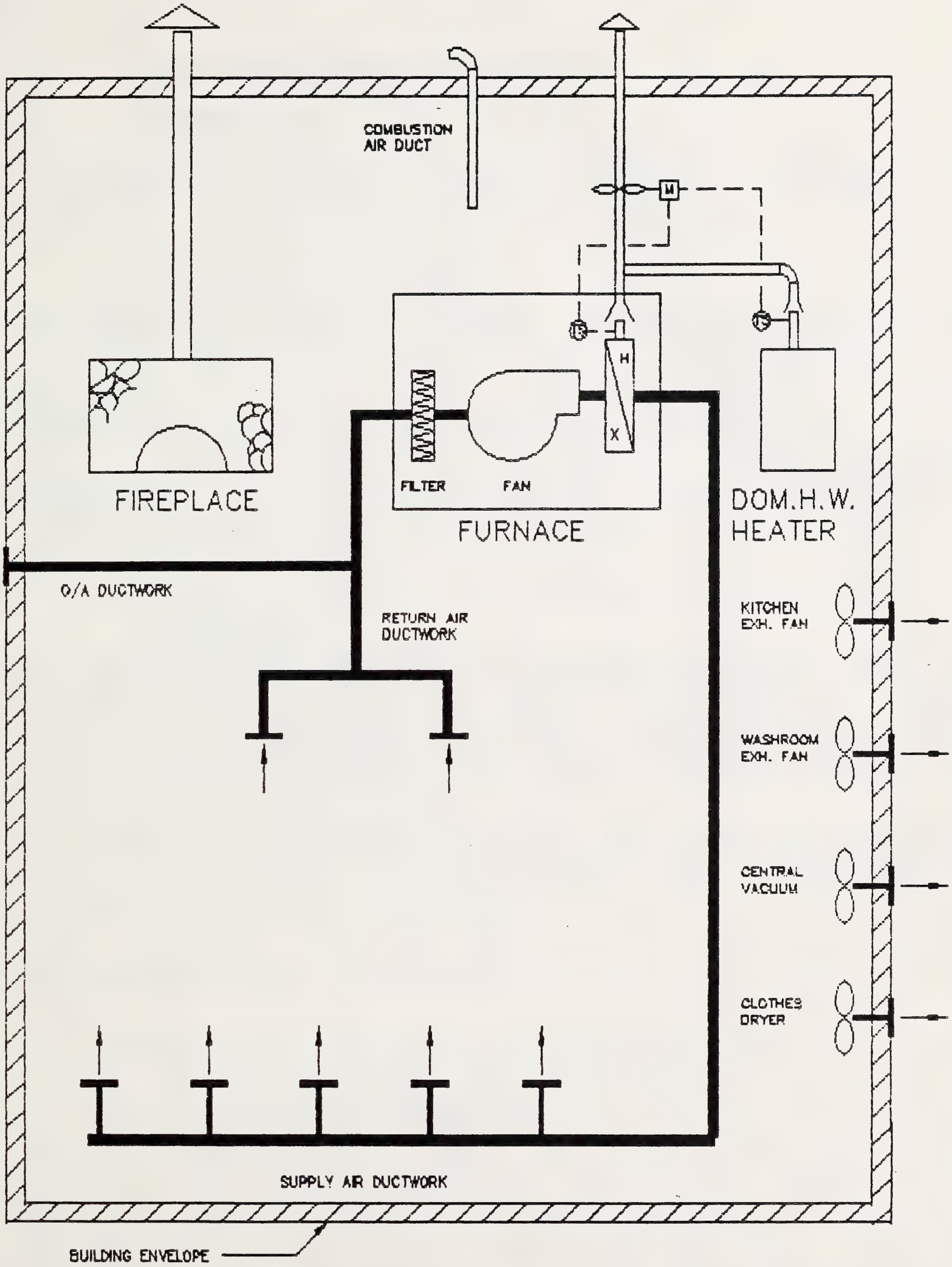
Fig 4.4



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INDUCED DRAFT FAN

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Fig 4.5

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter summarizes the major findings of the study. Recommendations to improve various situations are presented.

5.2 AIR QUALITY IN HOUSING

The number of pollutants affecting the air quality in housing is increasing daily as new products and materials are introduced to the marketplace. There is insufficient data available to assess the long term health effects of these contaminants or to define safe pollutant concentrations. More medical research into the subject is required. In the meantime, steps should be taken to increase the minimum required ventilation rates in housing. Removing tobacco smoke from the indoor environment would eliminate a major source of indoor air pollution which is known to be hazardous.

5.3 BACKDRAFTING

Air tightening the envelope of an existing house should be accompanied by a retrofit of the existing mechanical system. Atmospheric gas-fired appliances should be equipped with a draft inducer that would start when backdrafting is sensed at the draft diverter. Wood stoves and fireplaces should be atmospherically uncoupled.

New houses, constructed with "airtight" building envelopes should have induced draft appliances or atmospherically uncoupled appliances installed. Wood stoves and fireplaces should be atmospherically uncoupled.

Heat recovery ventilators should not be relied upon to prevent backdrafting.

The combustion air requirements outlined in Standata 85-DI-017, are not adequate to ensure that backdrafting will not occur. Although the combustion air requirements outlined will result in an adequate quantity of combustion air, there is no guarantee that the air provided by this system will be used for combustion air. It could be used to make-up for clothes drier exhaust for example. The Alberta Building code should require that sufficient heated outside air be introduced into a residence to satisfy the combined requirements of all air consuming appliances and devices, preventing dangerous negative pressures, unless induced draft or sealed combustion appliances are installed.

5.4 MOISTURE

Moisture problems result from any combination of excessive moisture generation rates within the space, inadequate dehumidification air, a positive pressure inside the space with respect to outdoors, or a discontinuous air vapour barrier. All of these parameters should be investigated in any attempt to eliminate a moisture problem.

In general, outside air quantities recommended by ASHRAE should be adequate to control moisture problems unless there is an excessive amount of moisture generated within the space.

5.5 COST EFFECTIVE LEVELS OF INSULATION

Cost effective levels of insulation vary with construction costs and the price of energy. At the time this study was undertaken, the following conclusions could be drawn:

Installing RSI 8.8 (R-50) in the ceiling instead of the code required RSI 6 (R-34) is not cost effective.

Basement walls should be insulated with at least RSI 2.1 (R-12). This insulation should be run from the basement ceiling level to the basement floor.

Above grade walls constructed using 2 x 6 studs with batt insulation or 2 x 4 walls with batt insulation and 38 mm (1 1/2 inches) of rigid insulation are recommended. These walls have an effective RSI 3.5 (R-20) insulation level. A 2 x 6 stud wall with batt insulation and 38 mm (1 1/2 inches) of rigid insulation resulting in RSI 4.75 (R-27) was not found to be cost effective.

Installing 25 mm (1 inch) of rigid insulation below the basement floor slab cannot be justified economically.

Triple glazed windows are not cost effective.

5.6 COST EFFECTIVE COMBUSTION APPLIANCES

Mid-efficiency furnaces seem to be more cost effective than high efficiency units.

5.7 AIR TIGHTNESS

Building airtight houses cannot be justified strictly on the basis of the energy saved. This is especially true if the additional expenses incurred in providing sufficient heated outside air are included in the analysis.

5.8 VENTILATION STRATEGIES

There are two basic ventilation strategies for housing, balanced systems and negative pressure systems. Balanced systems cannot be accomplished simply by using a heat recovery ventilator. A true balanced system would require that the outside air quantity introduced into a house be varied in response to the instantaneous sum of air exhausted. This could be accomplished by installing an economizer system which would vary the outside air quantity in response to the differential pressure across the building envelope. Further research is necessary to develop a simple, cost effective, balanced ventilation system for housing.

A negative pressure system would accept the fact that a negative pressure across the building could occur under certain modes of operation. Provisions to prevent downdrafting through chimneys would have to be incorporated into the design. Fuel fired devices would have to be equipped with draft inducers or be atmospherically uncoupled from the house. A negative pressure within the house would promote drafts (unless the building envelope was relatively airtight). A negative pressure within the house would reduce the problems associated with concealed condensation.

BIBLIOGRAPHY

BIBLIOGRAPHY

A MATHEMATICAL MODEL FOR PREDICTING ATTIC VENTILATION RATES REQUIRED FOR PREVENTING CONDENSATION ON ROOF SHEATHING; D. Burch, D. Luna; ASHRAE Transaction; V.86, Pt 1; 1980.

A METHOD OF DETERMINING SAFE VENTING PRESSURES IN DWELLINGS WITH CHIMNEYS AND COMPETING EXHAUST DEVICES; Sebastian Moffatt Sheltair Scientific; Canadian General Standards Board; Feb. 22 1986.

A NEW APPROACH TO AFFORDABLE LOW ENERGY HOUSE CONSTRUCTION; J. W. Lstiburek, J. K. Lischkoff; Alberta Department of Housing; July 1984.

A STUDY OF THE PERFORMANCE OF SIX RESIDENTIAL NATURAL GAS FURNACES; J.F. Kasha, J.D. Dale; Department of Mechanical Energy, University of Alberta; May 1986.

AIR INFILTRATION MODEL FOR RESIDENCES; G. Reeves, M. McBride, C. Sepsy; ASHRAE Transaction; V.85, Pt 1; 1979.

AIR-VAPOUR BARRIERS; D. Eyre and D. Jennings; reprinted by Energy Mines and Resources Canada ECOSB; fourth edition.

AN AIR INFILTRATION MODEL FOR MODERN SINGLE FAMILY DWELLINGS; R. Macriss, J. Cole, T. Zawacki; Presented at the 72nd Annual Meeting of APCA; Institute of Gas Technology; Chicago, Illinois; June 1979.

APPROACHES TO EVALUATION OF AIR INFILTRATION ENERGY LOSSES IN BUILDINGS; A. Blomsterberg, D. Harrje; ASHRAE Transaction; Vol. 85, Pt 1, 1979.

ASHRAE HANDBOOK 1985 FUNDAMENTALS; American Society of Heating, Refrigeration and Air Conditioning Engineers Inc.; 1985.

ASHRAE HANDBOOK 1984 SYSTEMS; American Society of Heating Refrigeration and Air Conditioning Engineers Inc.; 1985.

ASHRAE HANDBOOK 1983 EQUIPMENT; American Society of Heating, Refrigeration and Air Conditioning Engineers Inc.; 1985.

ASHRAE HANDBOOK 1982 APPLICATIONS; American Society of Heating, Refrigeration and Air Conditioning Engineers Inc.; 1985.

BILLPAYERS GUIDE TO HEATING SYSTEMS; Energy , Mines and Resources Canada; April 1983.

COMBUSTION-DERIVED INDOOR AIR POLLUTANTS RELEASED DURING CHIMNEY FAILURE SCENARIOS: A REVIEW OF THE LITERATURE (1983-1986) AND RECOMMENDATIONS FOR MONITORING; OEEC Consultants Inc.; Sheltair Scientific Ltd.; no date.

CONDENSATION IN ELECTRICALLY HEATED HOUSES; H. Orr; Division of Building Research; NRC; 1975.

CONDENSATION IN THE HOME: WHERE, WHY AND WHAT TO DO ABOUT IT; Canada Mortgage and Housing Corporation; Ottawa; Revised 1984.

CONSTRUCTION EXPERIENCE USING THE AIRTIGHT DRYWALL APPROACH; J. W. Lstiburek, P.Eng.; Alberta Department of Housing; March 1985.

CORRELATING MEASURED INFILTRATION FOR WIND FROM A SINGLE DIRECTION; D.J. Wilson, W. Pittman; ASHRAE Transactions 1983, Vol. 89, Pt 2 A & B.

DANGER: BACKDRAFTING CHIMNEYS; Sebastian Moffatt; Rodale's New Shelter, November/December, 1984.

DIRECT VENT WATER HEATER TEST; P.F. Edwards, D. Gianni; Energy Mines and Resources Canada, Energy Conservation and Oil Substitution Branch; January 1986.

EFFECT OF BUILDING SHAPE WIND SHELTER AND OPENINGS ON AIR INFILTRATION; D.J. Wilson and D.E. Kiel; Department of Mechanical Engineering, University of Alberta; October 1985.

THE EFFECT OF EXHAUST FANS AND REMEDIAL MEASURES ON HOUSE DEPRESSURIZATION; T. Hamlin and B. Gray; Scandia-Sheltair Consortium Inc.; April 1986.

THE EFFECT OF MECHANICAL VENTILATION ON THE AIR LEAKAGE CHARACTERISTIC OF A TWO-STOREY DETACHED HOUSE; C.Y. Shaw; National Research Council Canada Division of Building Research; July 1983.

THE EFFECTS OF VENTILATION ON RESIDENTIAL AIR POLLUTION DUE TO EMISSIONS FROM A GAS-FIRED RANGE; Traynor, Apte, Dillworth, Hollowell, and Sterling; Environment International; Pergaman Press Ltd.; U.S.A.; Vol. 8; 1982.

THE EFFECTS OF WOODBURNING ON THE INDOOR RESIDENTIAL AIR QUALITY; Moschandreas, Zabransky, and Rector; Environment International; Pergaman Press Ltd.; U.S.A.; Vol. 4, pp.463-468; 1980.

ENERGY CONSERVATION AND INDOOR AIR POLLUTION; S. Silberstein; Energy and Buildings, 2(1979); Netherlands; pp.185-189.

FIELD EXPERIENCES WITH AIR-TO-AIR HEAT EXCHANGERS THE REAL STORY; M. Schell and D. Rogoza; Conservation in Buildings: Northwest Perspective; Conference Proceedings; May 1985.

FIELD STUDIES OF DEPENDENCE OF AIR INFILTRATION ON OUTSIDE TEMPERATURE AND WIND; N. Malik; Energy and Buldings, Vol. 1, No. 3; Chicago, Il.; April 1978.

FINAL REPORT ON THE ALBERTA HOME HEATING RESEARCH FACILITY; M.Y. Ackerman, J.D. Dale, T.W. Forest, G.W. Sadler, D.J. Wilson and M. Zaheeruddin; Department of Mechanical Engineering, University of Alberta; February 1983.

FINE PARTICLE RESIDENTIAL INDOOR AIR POLLUTION; D . Moshchandreas, J. Winchester, J. Nelson, and R. Burton; Atmospheric Environment, Vol. 13, pp.1413-1418; Pergamon Press Ltd., Great Britain; 1979.

FRESH AIR INTAKE FOR FIREPLACE; Dr. M.A. Hatzinikolas, P.Eng.; Alberta Department of Housing; April 1984.

HAZARDOUS HEATING AND VENTILATING CONDITIONS IN HOUSING; Hatch Associates Ltd.; Research Division Policy Development and Research Sector CMHC; Toronto, Ontario; no date.

HEATING SYSTEM-GENERATED INDOOR AIR POLLUTION; S. Silberstein; Energy and Buildings, Vol. 2, 1979.

HEAT RECOVERY VENTILATION FOR HOUSING; National Centre for Appropriate Technology; DOE/CE/15095-9; February 1984.

HUMIDITY, CONDENSATION AND VENTILATION IN HOUSES; Proceedings of the Building Science Insight '83; Division of Building Research NRC; Ottawa; May 1984.

HYBRID SIMULATION OF A RESIDENTIAL GAS-FIRED FORCED AIR HEATING SYSTEM AND SUBSEQUENT PREDICTION OF ENERGY SAVINGS OBTAINABLE THROUGH MODIFICATION TO SYSTEM OPERATION; J. W. MacArthur, L. W. Nelson; Summer Computer Simulation Conference; pp.766-771; 1978.

IDENTIFYING VENTILATION TROUBLED HOUSES; J.H. White; Research Division CMHC; March 1984.

INDOOR AIR POLLUTION; J. Repace; Environment International, Vol. 8, Permagon Press Ltd.; U.S.A.; 1982.

INDOOR AIR POLLUTION AND HOUSING TECHNOLOGY; B.M. Small and Associates Ltd.; Planning Division Policy Development and Research Sector CMHC; Canada; August 1983.

INDOOR AIR POLLUTION DUE TO CHIPBOARD USED AS A CONSTRUCTION MATERIAL; I. Anderson, G.R. Lundquist, and L. Molhave; Atmospheric Environment, Vol. 9 pp.1121-1127; Permagon Press; Great Britain; 1975.

INDOOR AIR POLLUTION DUE TO ORGANIC GASES AND VAPOURS OF SOLVENTS IN BUILDING MATERIALS; Lars Molhave; Environment International, Vol. 8, pp.117-127; Permagon Press Ltd.; U.S.A.; 1982.

INDOOR AIR POLLUTION: PROBLEMS AND SOLUTIONS; S.E. Frazier; Specifying Engineer; Longwood, Fla.; October 1984.

INDOOR AIR QUALITY IN TIGHT HOUSES: A LITERATURE REVIEW; D. Coon; Housing Conservation Unit, Ontario Ministry of Municipal Affairs and Housing; Ecology House; December 1984.

INDOOR POLLUTANTS; National Research Council; National Academy Press; Washington, D.C.;December 1984.

INDUCED DRAFT WATER HEATER TEST; P.F. Edwards, D. Giannini; Energy Mines and Resources Canada, Energy Conservation and Oil Substitution Branch; January 1986.

INDUSTRIAL VENTILATION - A MANUAL OF RECOMMENDED PRACTICE; Committee on Industrial Ventilation; American Conference of Governmental Industrial Hygienists; 1980.

INSTITUTIONAL ASPECTS OF INDOOR AIR POLLUTION IN ENERGY EFFICIENT RESIDENCES; J.J. Everett, and T.J. Dreher; Environment International, Vol. 8, pp.525-531; Permagon Press Ltd., U.S.A.; 1982.

LOW ENERGY HOME DESIGNS; Home - Community Design Branch; Energy Conservation Branch, Alberta Energy and Natural Resources; November 1983.

MECHANICAL VENTILATION WITH HEAT RECOVERY FOR SUPERINSULATED HOUSES; J. J. Cooley; Conservation in Buildings: Northwest Perspective, Conference Proceedings; U.S.A.; May 1985.

METHODS FOR ESTIMATING AIR CHANGE RATES AND SIZING MECHANICAL VENTILATION SYSTEMS FOR HOUSES; National Research Council Canada Division of Building Research; November 1985.

MOISTURE PROBLEMS IN HOUSES; A.T. Hansen; Canadian Building Digest Division of Building Research; May 1984.

NATURAL AND MECHANICAL VENTILATION RATES IN A DETACHED HOUSE: MENSUREMENTS; D. Etheridge, L. Martin, R. Gale, and M. Gell; Applied Energy, Vol. 8 pp.1-18; Applied Science Publishers Ltd.; England; 1981.

NATURAL AND MECHANICAL VENTILATION RATES IN A DETACHED HOUSE: PREDICTIONS; D. Alexander and D. Etheridge; Applied Energy, Vol. 10 pp.79-95; Applied Science Publishers Ltd.; England; 1982.

OUTDOOR SOURCES OF INDOOR POLLUTION; S. Silberstein; Energy and Buildings, Vol. 2 pp.55-64; Netherlands; 1979.

PERFORMANCE OF NATURAL GAS FURNACES; J.D. Dale, J. Kasha; Department of Mechanical Engineering, University of Alberta; October 1984.

PRELIMINARY PERFORMANCE ASSESSMENT OF THREE VENTILATION SYSTEMS EMPLOYING AIR-TO-AIR HEAT EXCHANGERS; R.J. Corbett, B.A. Miller, and D.A. Hagan; Conservation in Buildings: Northwest Perspective, Conference Proceedings; U.S.A.; May 1985.

RADON DAUGHTER GROWTH WITH CONTINUOUS RADON INFLUX AND VARIOUS VENTILATION RATES; R.T. Beckman and R.F. Holub; U.S. Department of Labour; 1979.

RESEARCH ON REMEDIAL MEASURES - REMEDIAL MEASURES FOR GAS-FIRED APPLIANCES; Scandia Consultants Ltd.; Canada Mortgage and Housing Corporation; May 1986.

RESIDENTIAL COMBUSTION SAFETY CHECK LISTS - RESEARCH REPORT; Sheltair Scientific Ltd.; The Research Division Policy Development and Research Sector CMHC; Vancouver, B.C.; December 1984.

RESIDENTIAL COMBUSTION VENTING FAILURES - CASE STUDIES OF PROBLEM HOUSES: A FOLLOW-UP TO THE CANADA WIDE SURVEY; Sheltair Scientific and Scandia-Sheltair Consortium; The Research Division Policy Development and Research Sector CMHC; March 31 1986.

RESIDENTIAL COMBUSTION VENTING FAILURES - A SYSTEMS APPROACH - INDOOR AIR QUALITY MONITORING PROCEDURES AND PILOT TEST RESULTS; Sheltair Scientific Ltd. and Scandia-Sheltair Consortium Inc.; The Research Division Policy Development and Research Sector CMHC; March 31 1986.

THE ROLE OF WOOL CARPETS IN CONTROLLING INDOOR AIR POLLUTION; G. Crawshaw; Textile Institute and Industry; January 1978.

STRATEGIES FOR HEALTHFUL RESIDENTIAL ENVIRONMENTS; K.H. Raab; Canada Mortgage and Housing Corporation; June 1984.

STUDIES ON INDOOR AIR QUALITY IN CANADIAN HOMES - RESEARCH AND INFORMATION BASE; B. Small and Associates Limited; Research Division, CMHC; Ottawa; January 1985.

THE THERMAL FLOW PERFORMANCE OF FURNACE FLUES IN HOUSES; Scandia Consultants Limited; Canada Mortgage and Housing Corporation; File No. 5820-37; Ottawa; March 1985.

THE USER'S INFLUENCE ON AIR INFILTRATION; B. Kvisgaard; Air Infiltration Review, Vol. 6 No. 4; August 1985.

VENTILATION AND AIR QUALITY IN HOMES; An Enerwise Publication; Saskatchewan Power Corporation; August 1984.

VENTILATION FOR CONTAMINATION CONTROL; J. Kwan,P.Eng.; Alberta Workers Health, Safety and Compensation; January 1986.

WIND AND TEMPERATURE INDUCED PRESSURE DIFFERENTIALS AND EQUIVALENT PRESSURE DIFFERENCE MODEL FOR PREDICTING AIR INFILTRATION IN SCHOOLS; C. Y. Shaw; ASHRAE Transactions, Vol 86, pp.268-279; 1980.

APPENDIX "A"

SUMMARIES FROM THE LITURATURE REVIEW

APPENDIX A LITERATURE REVIEW

A.1 INTRODUCTION

This chapter summarizes a review of published information related to heating and ventilation of modern housing.

The publications reviewed have been divided into five major categories as follows:

1. indoor air quality in housing;
2. safety and backdrafting of combustion appliances;
3. moisture control;
4. ventilation and infiltration; and
5. heat recovery ventilators.

Some of the publications fit into more than one category. These reports are listed under the category that is most representative.

A.2 AIR QUALITY IN HOUSING

Listed below are summaries of publications that address the subject of air quality in housing.

A.2.1 THE EFFECTS OF WOODBURNING ON THE INDOOR RESIDENTIAL AIR QUALITY; Moschandreas, Zabransky, and Rector; Environment International, Vol. 4, 1980.

PURPOSE:
This paper examines the effects of woodburning on the quality of indoor air in residences.

SCOPE:
The effects of woodburning on total suspended particulate matter (TSP), respirable suspended particulate matter (RSP), benzo-a-pyrene (BaP) and gaseous pollutants were examined. The health hazards associated with these substances are not discussed in detail.

METHODOLOGY:
Three dwellings with a woodburning stove or fireplace were monitored for two weeks each. Data were collected from outdoors and at three indoor zones within each residence. Monitoring was undertaken while normal occupant activity was ongoing. Gas phase sampling was performed three times each hour for each zone. Sampling of particulate matter was integrated over 24 hours for each zone.

MAJOR CONCLUSIONS:
Elevated indoor concentrations of TSP, RSP, and BaP are due to the operation of woodburning appliances.

Average indoor TSP concentrations during woodburning periods were about three times as high as corresponding levels during non-woodburning periods.

Indoor BaP concentrations during woodstove use averaged five times more than during non-woodburning periods.

The elevated levels of these pollutants attributed to woodburning may have long term health implications.

A.2.2 INDOOR AIR POLLUTION: PROBLEMS AND SOLUTIONS; Frazier; Specifying Engineer, October, 1984.

PURPOSE:
This paper describes the various types of indoor pollutants and their sources. Various methods of pollution control are explained.

SCOPE:
This study addresses buildings in which relatively low levels of a large number of pollutants are found. These situations are found throughout commercial/industrial/institutional buildings.

METHODOLOGY:
The author divides pollutants into two classes, namely particulate and molecular. He explains the types and sources of pollution in both classes and offers solutions to reduce the pollution levels.

MAJOR CONCLUSIONS:
Particulate pollutants consist of tobacco smoke, house dust, asbestos fibres, and glass fibres.

Molecular pollutants consist of formaldehyde, radon, organic solvents, combustion products, and human odors.

Traditionally, these pollutants have been removed by whole building ventilation. Air to air heat exchangers reduce the operating cost by recovering heat but they have a high capital cost.

Particulates can be removed by mechanical filtration. Small particles (less than 5 micrometres) must be removed.

Molecular pollutants can be removed by absorption.

Polar molecular pollutants such as formaldehyde, nitrogen oxides and most odors are usually absorbed well by alumina or silica gel.

Nonpolar molecular pollutants such as most organic solvents are absorbed by activated charcoal.

The author's long term solution to indoor air pollution is to clean the air in the building HVAC system rather than resorting to methods which require large amounts of expensive outdoor air for dilution control.

A.2.3 INSTITUTIONAL ASPECTS OF INDOOR AIR POLLUTION IN ENERGY EFFICIENT RESIDENCES; Everett, Dreher; Environment International, Volume 8, 1982.

PURPOSE:
This paper examines the institutional mechanisms that may be used to prevent the occurrence of unhealthy indoor environments. The potential legal ramifications of such unhealthy conditions are outlined.

SCOPE:
This study addresses air quality in the housing industry from a legal perspective.

METHODOLOGY:
The authors summarize the research devoted to indoor air pollution. They outline potential mechanisms by which various levels of government, industry, and professional organizations can ensure adequate indoor air quality. Finally, the authors outline the legal implications of poor indoor air quality citing several precedences.

MAJOR CONCLUSIONS:
Indoor air pollution can potentially occur in energy-efficient residences.

The building industry is potentially liable for problems resulting from poor indoor air quality.

Because of an existing scarcity of regulations concerning indoor air pollution, private lawsuits in civil courts may eventually be instrumental in establishing maximum allowable indoor air pollution levels.

A.2.4 INDOOR AIR POLLUTION DUE TO ORGANIC GASES AND VAPOURS OF SOLVENTS IN BUILDING MATERIALS; Molhave; Environment International, Vol. 8, 1982.

PURPOSE:
This paper examines the emission of organic gases and solvent vapours from common building materials. The author establishes a mathematical model to predict pollution concentrations. Potential health risks due to these pollutants are discussed.

SCOPE:

Emissions rates from 42 commonly used building materials are measured at standard atmospheric conditions. The materials were segregated into five major groups as follows:

1. floor only;
2. floor and ceiling;
3. walls;
4. casings, frames, sills; and
5. sealant and caulking

METHODOLOGY:

Samples of the test materials with 0.25 m2 surface area were put in a 1m3 stainless steel test chamber. The test chamber was supplied with fresh air at the rate of 1 air change per day. The fresh air was at 21.1oC and 35-40% RH.

Air leaving the chamber was analyzed using gas chromatography, mass spectrometry, and a panel of trained judges.

A mathematical model was developed to predict the concentrations of pollutants originating from the building materials examined.

MAJOR CONCLUSIONS:

Building materials may be the main source of organic gases and vapours in the indoor home environment.

The mathematical model results in calculated results that agree satisfactorily with measured results.

The possibility of negative health effects cannot be ignored especially for a portion of the population that has become sensitive to low levels of indoor pollution due to continuous exposure.

A.2.5 INDOOR AIR POLLUTION; J. Repace; Environment International, Vol. 8, 1982

PURPOSE:

This paper examines types and sources of indoor air pollutants.

SCOPE;

Gaseous and particulate air pollutants found in American buildings are covered by this report.

METHODOLOGY:

The author examines indoor pollutants on an individual by pollutant basis. The effects of these pollutants on building occupants are discussed. The problems facing legislators attempting to address the problems associated with indoor pollution are outlined.

MAJOR CONCLUSIONS:
The Clean Air Act should be extended to include the indoor environment.

Research and development in the field of pollutant level measurement must be increased.

New product standards aimed at reducing sources of indoor pollutants should be developed.

Building codes and standards should be expanded to include a requirement specifying the use of a below slab vapour barrier to reduce radon infiltration into buildings.

Automatic sensors should control HVAC systems in response to pollution levels.

A.2.6 STUDIES ON INDOOR AIR QUALITY IN CANADIAN HOMES, RESEARCH AND INFORMATION BASE; B.M. Small and Associates Limited; Research Division, CMHC, January 1985.

PURPOSE:
This publication provides a reference document on indoor air quality for researchers in the field.

SCOPE:
The paper outlines research that has been undertaken by Canadian individuals, corporations, and government agencies. This document also provides an information base which outlines the sources of written information on indoor air quality.

SUMMARY:
The report is divided into two parts, a research base and an information base.

The research base describes the research, identifies the research organization and the funding organization, and lists the publications resulting from the research. The name, address and phone number of the principal researcher are provided to enable the reader to contact the source directly.

The information base lists periodicals containing articles relating to indoor air quality. The information base also explains how to access information from libraries and computer data bases.

Five separate types of index help to make this report an extremely useful research tool.

A.2.7 INDOOR POLLUTANTS; National Research Council (U.S.A.), National Academy Press, December, 1984.

PURPOSE:

This report characterizes the quality of the indoor environment with respect to air pollutants and assesses the adverse health effects of these pollutants.

SCOPE:

This study reviews and appraises the available knowledge on indoor air pollution. The paper focuses on the indoor environment with the exception of industrial working environments. The indoor pollutants examined were selected on the basis of evidence that they cause human illness or material damage. Pollutants examined include radon and its decay products, formaldehyde and other organic substances, asbestos and glass fibres, combustion products, tobacco smoke, consumer products, odours, and humidity.

The sources and characterization of indoor pollution are outlined. The health effects of indoor pollution are discussed. Methods of controlling indoor pollutants are examined. Factors that influence indoor pollution are discussed. Methods of measuring indoor pollution and exposures are outlined.

METHODOLOGY:

The report was prepared by a group of authors selected on the basis of their expertise. The report was reviewed by a committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

MAJOR CONCLUSIONS:

The major conclusions of this study are as follows:

(a) Radon

The major sources of radon contamination are radium-bearing building materials, subsurface soil and groundwater. Radon undergoes radioactive decay, resulting in alpha-emitting decay nuclides in particulate form. Radon and radon daughter products increase the likelihood of lung cancer. Radon concentrations have been shown to be much higher indoors than outdoors.

(b) Formaldehyde

Sources of formaldehyde in the indoor environment are building materials (plywood, particle-board and urea-formaldehyde insulation), combustion appliances and tobacco smoke. This pollutant causes irritation of the respiratory tract and eyes, nausea, headache and rashes. It has been linked to increased instances of nasal cancer. Formaldehyde concentrations are almost always higher indoors than outdoors.

(c) Indoor Combustion

Gas-fired stoves and other unvented combustion appliances are major sources of indoor air pollution. Increased levels of carbon dioxide, carbon monoxide, and nitrogen oxides result from the use of these unvented combustion appliances.

(d) Smoking

Smoking is the major source of indoor air pollution. Elevated levels of cancer causing particulates and gaseous combustion products can be attributed to smoking.

(e) General

Efforts to improve indoor air quality should concentrate on reducing the number and strength of pollutant sources. New instruments to measure indoor pollutant levels need to be developed.

A.2.8 INDOOR AIR POLLUTION AND HOUSING TECHNOLOGY; B.M. Small and Associates Ltd.; Planning Division, Policy Development and Research Sector, CMHC; August, 1983.

PURPOSE:
This report was prepared to help remedy the lack of readily available information on indoor air quality in Canada.

SCOPE:
This study reviews and summarizes the scientific literature on indoor air pollution.

SUMMARY:
The author examines major pollutants individually giving a brief description, major sources, concentration ranges, standards, incidence, and health effects.

The author discusses how indoor pollution affects various groups of people. He also discusses the medical unknowns associated with indoor pollution.

Sources of indoor pollutants and factors that aggravate indoor pollutants are outlined.

Factors that reduce indoor pollution are examined.

The author outlines low pollution design and construction methods with reference to his own low pollution house.

MAJOR CONCLUSIONS:
Many materials and conditions contribute to indoor air pollution in Canada. Radon gas, nitrogen dioxide, carbon monoxide and formaldehyde pose the greatest health hazard. Improperly installed or maintained combustion equipment can contribute to indoor air pollution. This situation can result in the death of the building occupants.

Many people are more susceptible to indoor air pollution than others. This susceptibility can vary with time. There is evidence that the proportion of people who are becoming sensitive to low levels of various pollutants is increasing.

Smoking is the major source of indoor pollution in Canada. Sidestream smoke has an adverse effect on the health of non-smokers. Using outside air to dilute cigarette generated pollution to acceptable levels would result in prohibitive energy consumption.

Certain energy conservation techniques can aggravate indoor air pollution. Reducing natural ventilation rates by tightening building envelopes, reducing mechanically induced outside air quantities, and the use of volatile insulation materials such as urea formaldehyde insulation are examples.

There are significant medical unknowns associated with indoor pollution.

A.2.9 INDOOR AIR QUALITY IN TIGHT HOUSES: A LITERATURE REVIEW; D. Coon; Housing Conservation Unit, Ontario Ministry of Municipal Affairs and Housing, December 1984.

PURPOSE:
This literature review is intended to provide an overview of the potential indoor air quality problems resulting from air sealing of residential buildings.

SCOPE:
The study summarizes the nature and sources of indoor air contaminants, reviews methods of measuring air change rates in housing, and reviews literature pertaining to the improvement of indoor air quality.

METHODOLOGY:
The author reviews the question of air quality, making frequent reference to existing literature.

MAJOR CONCLUSIONS:
Meaningful residential indoor air quality standards cannot be formulated because not enough is known about long term exposure to low levels of pollutants.

Individual houses vary so much with respect to ventilation rates that it is almost impossible to predict changes in air quality resulting from air tightening. This problem is compounded by the fact that there does not seem to be any accurate method of measuring air changes in housing.

Mechanical ventilation is necessary to ensure acceptable indoor air quality.

A.2.10 OUTDOOR SOURCES OF INDOOR POLLUTION; Samuel Silberstein; Energy and Buildings, 2 (1979) 55-64.

PURPOSE:
The purpose of this paper is to examine the effects of outdoor pollution levels on indoor pollution levels.

SCOPE:
The authors use a mathematical model to predict the interrelationship between indoor pollution levels, outdoor pollution levels, and ventilation air change rate.

METHODOLOGY:
Outdoor pollution levels are assumed to vary cyclicly. With a constant air exchange rate, indoor pollution levels are assumed to vary cyclicly. Fourier series analysis is used to determine the relationship between the indoor and outdoor pollution levels.

MAJOR CONCLUSIONS:
Lowering the air change rate will reduce indoor pollution levels if the outdoor pollution peak level is high compared with the average outdoor pollution level, and if the outdoor peak level has a short duration. An example of this situation is pollution due to rush hour traffic.

With the exception of the above case, lowering the air change rate will increase indoor air pollution levels. This is because indoor sources of pollution are more important than outdoor sources.

A.2.11 FINE PARTICLE RESIDENTIAL INDOOR AIR POLLUTION; D. Moschandreas, J.W. Winchester, J. Nelson, and R. Burton; Atmospheric Environment, Vol. 13, pp 1413-1418, 1979.

PURPOSE:
This study was undertaken to test a new experimental approach to determining indoor-outdoor relationships between particular pollutants.

SCOPE:
Indoor-outdoor relationships between the following particulate pollutants in three residences were examined: sulfur, lead, bromine, potassium, and iron.

METHODOLOGY:
Proton-induced x-ray emission analysis was applied to time sequence "streaker' filter samples. The samples were continuously collected at each of three sites for a period of seven days. Pollutants were measured at one outdoor and two indoor stations for each site. All results were presented graphically for comparison.

MAJOR CONCLUSIONS:
Potassium is the only pollutant studied whose primary source is of indoor origin.

Sulfur, lead and bromine particulates are primarily of outdoor origin.

Iron particulate concentrations are lower indoors than outdoors due to settling and surface deposition because the particle size is large compared with the other pollutants.

A.2.12 ENERGY CONSERVATION AND INDOOR AIR POLLUTION;
S. Silberstein; Energy and Buildings, 2(1979) 185-189.

PURPOSE:
The purpose of this paper is to examine the relationship between indoor generated air pollution and building air change rate.

SCOPE:
Heating system generated pollutants and pollutants due to cooking with a gas range are covered in this report.

METHODOLOGY:
The author derives a mathematical model that is used to predict changes in indoor pollution levels resulting from changes in whole house ventilation rate.

MAJOR CONCLUSIONS:
Reducing the whole house air change rate to twenty-five percent of its present value will triple heating system generated indoor air pollution.

Pilot lights should be eliminated as a first step towards improving indoor air quality.

Effective kitchen ventilation systems should be installed.

A.2.13 THE ROLE OF WOOL CARPETS IN CONTROLLING INDOOR AIR POLLUTION; G. Crawshaw, Textile Institute and Industry, January 1978.

PURPOSE:
This report examines the relationship between indoor air pollution and the presence of wool carpets.

SCOPE:
The study deals with sulphur dioxide pollution.

METHODOLOGY:
Radioactively labelled sulphur dioxide was used to determine the absorption of sulphur dioxide by wool carpet. Samples of wool carpet were enclosed in a test chamber and exposed to a stream of air containing sulphur dioxide 35. The air entering and leaving the chamber was monitored using a Geiger counter to determine the amount of sulphur dioxide absorbed by the carpet.

MAJOR CONCLUSIONS:
Wool carpets provide an excellent sink for sulphur dioxide pollution inside buildings. The absorption continues over long periods of time due to the high acid combining potential of wool.

A.2.14 INDOOR AIR POLLUTION DUE TO CHIPBOARD USED AS A CONSTRUCTION MATERIAL; I. Andersen, G. Lundquist, and L. Molhave; Atmospheric Environment, Vol. 9, 1975.

PURPOSE:
This paper examines the parameters influencing the rate of formaldehyde emanating from particleboard.

SCOPE:
A mathematical model examines the effects of air temperature, ventilation air change rate, and water vapour concentration on the equilibrium concentration of formaldehyde.

METHODOLOGY:
Formaldehyde levels in 23 dwellings were monitored for several months using a chromotropic acid method. Ventilation air change rates were simultaneously measured using a Kr-85 tracer gas decay method.

Test chamber measurements were also taken. Samples of particleboard were placed in an aluminum test chamber. Formaldehyde emanation rates at various temperatures, humidities, and air change rates were monitored.

Mathematical regression analyses were applied to the data collected.

MAJOR CONCLUSIONS:
Equilibrium formaldehyde concentrations were found to be directly proportional to temperature and water vapour concentration. Increasing ventilation rates result in a hyperbolic decrease of formaldehyde concentration. A mathematical model that agreed closely with experimental observations was developed.

Formaldehyde concentrations exceeding established threshold limits for continuous outdoor exposure could result from the use of chipboard as a construction material.

A.3 SAFETY AND BACKDRAFTING OF COMBUSTION APPLIANCES

Listed below are summaries of publications that address the subjects of safety and combustion venting.

A.3.1 DANGER: BACKDRAFTING CHIMNEYS; Sebastian Moffatt; Rodale's New Shelter, November/December 1984

PURPOSE:
This paper outlines the dangers associated with backdrafting chimneys and presents solutions to solve the problem.

SCOPE:
The study examines backdrafting in residential furnaces and fireplaces.

SUMMARY:
The physical symptoms of health complaints due to malfunctioning chimneys are outlined. The physical causes for backdrafting are explained. Air requirements of various appliances are quantified. Backdrafting problems due to fireplaces at low and high firing rates are discussed. A cure for backdrafting due to fireplace operation is presented.

Problems associated with backdrafting furnaces are examined.

A simple safety check for furnace chimneys is presented.

MAJOR CONCLUSIONS:
Backdrafting chimneys can kill the occupants of a house.

Low indoor air pressure is the most likely cause of backdrafting.

Simultaneous operation of exhaust fans and fireplaces can cause backdrafting.

Fireplaces are subject to backdrafting when they are cooling down.

When a fireplace is burning strongly, it can cause backdrafting in other appliances.

To cure backdrafting problems associated with fireplaces, airtight glass doors and an outside air duct should be installed.

A.3.2 HAZARDOUS HEATING AND VENTILATING CONDITIONS IN HOUSING; Hatch Associates Ltd.; Research Division, Policy Development and Research Sector, CMHC; no date.

PURPOSE:
This report was commissioned to examine the frequency, severity and causes of hazardous conditions due to inadequate venting of combustion products, specifically carbon monoxide.

SCOPE:
The report examines cases of carbon monoxide poisoning, fatal and non-fatal, on a province by province basis for the whole of Canada.

METHODOLOGY:
The author contacted various sources including governments, utility companies, universities, various associations, the media, and other knowledgeable groups and individuals by telephone to gather information. Data regarding incidents of carbon monoxide poisoning due to the inadequate exhaust of combustion products were collected by mail. The data were summarized on a province by province basis.

MAJOR CONCLUSIONS:
Carbon monoxide is responsible for almost all reported episodes of hazardous heating and ventilation conditions due to the inadequate exhaust of combustion products.

Equipment failures were implicated in 46% of the reported episodes. Damaged or blocked chimneys were second at 31%, followed by downdrafting of combustion gases at 25%, and improper equipment installation at 24%.

A.3.3 RESIDENTIAL COMBUSTION SAFETY CHECKLISTS - RESEARCH REPORT; Sheltair Scientific Ltd.; The Research Division, Policy Development and Research Sector CMHC; December 1984.

PURPOSE:
This report was commissioned as a result of the growing number of chimney failures in housing. Methods of identifying potentially hazardous venting situations are outlined.

SCOPE:
The authors provide two combustion safety checklists. One checklist was designed for the tradesman and the other checklist was designed for the householder. The checklists were designed to be general enough to accommodate natural gas, fuel oil, or wood.

METHODOLOGY:
A pilot research study of a small sample of houses in B.C. was conducted to determine how flues fail and help evaluate testing techniques. The checklists were then drawn up and tested on twenty homes in five regions across Canada. Remedial measures for failure houses were developed.

MAJOR CONCLUSIONS:
A comprehensive combustion ventilation safety check can be economically undertaken by a tradesman with less than $300 worth of equipment. Remedial measures, applied to problem houses, were able to cure the problems. Examples of these measures are as follows:

a) increase the mechanically supplied tempered outside air;

b) provide a direct air supply for clothes dryers;

c) install a thermo-disc on the draft hood for gas-fired water heaters to turn the appliance off in the event of flue gas spillage;

d) install a flue gas spillage alarm on atmospheric gas-fired furnaces; and

e) provide a direct combustion air supply to fireplaces.

A.3.4 THE THERMAL AND FLOW PERFORMANCE OF FURNACE FLUES IN HOUSES; Scanada Consultants Limited; Canada Mortgage and Housing Corporation; March 1985 (Unpublished).

PURPOSE:
This study examines the problem of chimney backdrafting.

SCOPE:
The mechanisms leading to backdrafting were studied mathematically. A computer model was developed, tested, and used to determine the sensitivity of chimney flow to various parameters.

METHODOLOGY:
The authors contacted various scientific authorities, completed a literature review, defined the relevant parameters, constructed a computer model, and verified the model.

MAJOR CONCLUSIONS:

The most important finding of this study is that it is not sufficient to provide outdoor air to satisfy the combustion requirements of the individual heating appliances. All of the outside air requirements of all appliances (e.g. fans, fireplaces, etc.) must be supplied with minimal house depressurization before safe combustion appliance venting can be assured.

Avoiding backdrafting during standby operation will ensure that backdrafting will not occur during start-up or full fire operation.

In tight houses, the use of atmospheric gas-fired furnaces should be avoided. If this is not possible, new installation techniques to prevent downdrafting must be developed and implemented.

A.3.5 THE EFFECT OF EXHAUST FANS AND REMEDIAL MEASURES ON HOUSE DEPRESSURIZATION; T. Hamlin and R. Gray; Saskatchewan Research Council Publication No. R-823-4-E-86, April 1986.

PURPOSE

This study examines the depressurizing effects of three selected exhaust appliances operating singularly and in combination. The study examines remedial measures to prevent excessive depressurization. The effects of wind on depressurization are investigated.

SCOPE

The authors examined the depressurization effects of an "Air King" 400-series range hood, a "Jenn-Air" C-201 counter top range, and a "Kenmore" HD clothes dryer. The effects of a "Torin" GP 250 fan used to pressurize the furnace area were examined.

METHODOLOGY

A test house was equipped with over 200 thermocouples, humidity sensors, and pressure taps. A standard meteorological station was installed in the back yard. Various combinations of exhaust appliances were operated. The effects of wind and remedial air supply were investigated.

MAJOR CONCLUSIONS

Pressure effects of exhaust appliances are transmitted throughout a house with negligible attenuation. Exhaust appliances exhibit interactional effects. Their combined performance is not simply the sum of their individual performance. Remedial air supplies without fans are not always successful in preventing dangerous levels of depressurization. Differential pressure control is a desirable feature of a house mechanical system.

A.4 MOISTURE CONTROL

Listed below are summaries of publications related to moisture control.

A.4.1 CONDENSATION IN THE HOME: WHERE, WHY, AND WHAT TO DO ABOUT IT; Canada Mortgage and Housing Corporation, Revised 1984.

PURPOSE:
The purpose of this study was to explain the reasons for condensation problems in housing and offer solutions to rectify the problems.

SCOPE:
The study examined condensation in all types of existing houses and offered advice to builders of new houses.

SUMMARY:
The basic principles concerning condensation were outlined. Sources of moisture within a house were quantified. Practical steps to control surface condensation and to reduce concealed condensation are outlined. Tips on preventing moisture from air leakage by ensuring a continuous air barrier in new building construction are presented. Techniques for moisture control in existing housing are explained. Modifications to the building envelope and ventilation retrofits are discussed.

MAJOR CONCLUSIONS:
Surface condensation in houses is a result of excessive humidity levels within the building.

Concealed condensation is caused mainly by the movement of moisture laden air into the building envelope.

To control surface condensation, the sources of moisture should be controlled.

To control concealed condensation, air leakage paths into the building envelope should be sealed.

A.4.2 AIR-VAPOUR BARRIERS; D. Eyre and D. Jennings; reprinted by Energy Mines and Resources Canada ECSB, fourth edition.

PURPOSE:
This publication provides a comprehensive treatment of the fundamentals and the practical problems associated with air-vapour barrier installations.

SCOPE:
The techniques outlined in the report apply to residential construction on the Canadian Prairies, specifically Saskatchewan.

METHODOLOGY

The author outlines the fundamentals of water vapour movement and control as it applies to residential construction. A comprehensive set of architectural details outline the installation of an air-vapour barrier. These details address all possible leakage paths that could occur in residential construction.

MAJOR CONCLUSIONS:

An airtight building envelope is necessary for energy efficient residential construction. The effects of the air-vapour barrier on combustion devices must be addressed. Careful planning and attention to detail during construction are necessary to produce an effective air-vapour barrier.

A.4.3 CONDENSATION IN ELECTRICALLY HEATED HOUSES; H. Orr; Division of Building Research, NRC, 1975.

PURPOSE:

This paper examines condensation in residential attics.

SCOPE:

The houses examined were well insulated, electrically heated and located in Northern Canada.

SUMMARY:

A housing project in Northern Canada had attic condensation problems. Doubling the ventilation free area did not solve the problem. An examination of the houses indicated the following problems:

- the relative humidity levels within the houses were too high
- the air barrier between the house interior and the attic was not continuous
- the absence of chimneys resulted in a higher air pressure at ceiling level
- high levels of ceiling insulation resulted in low attic temperatures

MAJOR CONCLUSIONS:

The vapour barrier between the house interior and the attic space should be airtight.

Lower humidity levels should be maintained within the houses.

The house interiors should be maintained at a negative pressure.

A.4.4 HUMIDITY, CONDENSATION AND VENTILATION IN HOUSES; Proceedings of the Building Science Insight'83; Division of Building Research NRC; May 1984.

PURPOSE:
This paper outlines the causes of and cures for moisture damage in buildings.

SCOPE:
The publication consists of four papers on humidity, condensation, and ventilation in houses that were presented at the 1983 Building Science Insight Seminar/Workshop.

SUMMARY:
The first paper outlines the types of moisture problems encountered across Canada, their regional distribution and probable causes.

The second paper examines the sources of moisture in houses.

The third paper explains the psychrometric principals involved with condensation. The concepts of moisture barrier and air barrier are discussed.

The fourth and final paper discusses both natural and mechanical ventilation in houses. Various types of mechanical ventilation systems are examined.

MAJOR CONCLUSIONS:
Moisture damage is apparent in approximately one percent of NHA housing stock. These problems are related to indoor temperature and humidity, the climate, and building envelope construction details. Action must be taken to prevent this percentage from increasing.

Moisture sources in problem houses should be identified and reduced before increasing the ventilation rate to cure the problem.

Air leakage is the major cause of condensation within wall and roof cavities. Both vapour barriers and air barriers are required to prevent these problems.

Mechanical ventilation is required to ensure adequate air quality in houses. Natural ventilation alone is not adequate.

A.4.5 MOISTURE PROBLEMS IN HOUSES; A.T. Hansen; Canadian Building Digest #231, May 1984.

PURPOSE
The purpose of this publication is to examine the causes of condensation problems and present ways of reducing or eliminating them.

SCOPE
This study pertains to residential buildings in Canada.

METHODOLOGY
The author outlines the sources of moisture that is added to indoor air. A table quantifies moisture generated in several sources. The ways that moisture can be removed from the building are discussed. Surface condensation and hidden condensation problems are discussed.

MAJOR CONCLUSIONS
If moisture is generated within a building faster than it is removed, moisture problems will develop. Only a small percentage of moisture generated within a space is removed by vapour diffusion. Most of the moisture generated within a building is removed by exchanging inside air with outside air. Increasing the amount of outside air can be used to control moisture problems.

A.5 VENTILATION AND INFILTRATION

Listed below are summaries of publications that deal with ventilation and filtration.

A.5.1 THE EFFECTS OF VENTILATION ON RESIDENTIAL AIR POLLUTION DUE TO EMISSIONS FROM A GAS-FIRED RANGE; Traynor, Apte, Dillworth, Hollowell, and Sterling; Environment International, Vol. 8, 182.

PURPOSE:
This paper shows the usefulness of a mathematical model for extrapolating environmental chamber results on pollutant emissions from combustion appliances to determine indoor pollutant concentrations in actual residences.

SCOPE:
This study investigates the effect of infiltration and two types of mechanical ventilation on indoor CO, CO2, and NOX concentrations from a gas-fired range.

METHODOLOGY:
An unoccupied one-story experimental research house was equipped with three internal air sampling sites, and one external air sampling site. CO, CO2, and NOX concentrations were measured every 24 minutes.

The effects of infiltration only, whole house mechanical ventilation, and spot ventilation on pollution levels were studied.

METHODOLOGY:
The single-equation model can be used to estimate indoor pollutant concentrations from combustion appliances.

Spot ventilation (using a range hood) is much more effective in removing pollutants from a point source than increasing whole-house ventilation.

A.5.2 NATURAL AND MECHANICAL VENTILATION RATES IN A DETACHED HOUSE: MEASUREMENTS; D. Etheridge, L. Martin, R. Gale, and M. Gell; Applied Energy 8(1981) 1-18.

PURPOSE:
This paper examines the air change rates in a detached house.

SCOPE:
Natural ventilation rates, air change rates resulting from exhaust fan use, air change rates resulting from supply fan use, and air change rates resulting from combined supply/exhaust fan use were determined. The effects of weatherstripping external windows and doors were assessed.

METHODOLOGY
A single, two-storey, four bedroom detached house was used in the study. Helium gas at an initial concentration of 0.8 percent was used (tracer gas decay method) to determine air change rate. Mathematical regression techniques were used on the data obtained to arrive at conclusions.

MAJOR CONCLUSIONS:
Weatherstripping the external doors and windows reduced the natural ventilation air change rate by approximately one-third.

Mechanical ventilation systems in British houses would lead to increased energy consumption compared with naturally ventilated houses.

A.5.3 NATURAL AND MECHANICAL VENTILATION RATES IN A DETACHED HOUSE: PREDICTIONS; D. Alexander and D. Etheridge; Applied Energy 10 (1982) 79-95.

PURPOSE:
This research attempts to correlate measured air change rates in a house with rates predicted by theory.

SCOPE:
The mathematical predictions are compared with measured air change rates for a single detached house in Great Britain.

METHODOLOGY:
The continuity equation is used to predict the flow of air through the building envelope. The mathematical model requires data on external pressures and the sizes and distribution of building openings.

The external pressures were determined using a model of the site in a wind tunnel.

Trial and error methods were used to predict the sizes and spatial distribution of building openings.

MAJOR CONCLUSIONS:
The authors claim encouraging agreement between theory and experiment. They do admit, however, that it is extremely difficult to predict the sizes and distribution of building openings.

A.5.4 A MATHEMATICAL MODEL FOR PREDICTING ATTIC VENTILATION RATES REQUIRED FOR PREVENTING CONDENSATION ON ROOF SHEATHING; D. Burch, D. Luna; ASHRAE Transaction, V.86, Pt. 1, 1980.

PURPOSE:
This research was undertaken to re-evaluate the ventilation requirements of attics with modern insulation values.

SCOPE:
The study is limited to residential attic spaces in the United States.

METHODOLOGY:
The authors built a mathematical model based on temperature and moisture balances of the attic space and its surroundings. The equations were programmed into a digital computer. Ventilation rates required to maintain the attic temperature above the dewpoint temperature were calculated for various levels of insulation and ceiling air penetration rates. The calculations were run for attics with and without vapour barriers. The calculations were also run for houses with and without humidification.

MAJOR CONCLUSIONS:
Required attic ventilation rates increase with increasing attic insulation rates, decreasing outdoor ambient temperatures, and increasing indoor relative humidity levels.

The attic ventilation rates outlined by ASHRAE and HUD appear to be adequate.

A.5.5 AIR INFILTRATION MODEL FOR RESIDENCES; G. Reeves, M. McBride, C. Sepsy; ASHRAE Transaction, V.85, Pt. 1, 1979.

PURPOSE:
The objective of this research was to develop a generalized computer model to predict hourly infiltration rates.

SCOPE:
This report is limited to infiltration in residences. Single storey, two storey, and split level houses are included.

METHODOLOGY:
Tracer gas techniques were applied to six houses and three apartments. Seven thousand data points were collected. Various mathematical models were developed and compared with the test data. The model which most accurately matched the test data (consistent with simplicity) was chosen.

MAJOR CONCLUSIONS:
The authors provide a computer program which is intended to be used to predict hourly infiltration values in houses for energy calculation purposes.

Determining infiltration rates in houses is complex due to the large number of interacting parameters, and the difficulty determining the magnitudes of some of the parameters.

A.5.6 APPROACHES TO EVALUATION OF AIR INFILTRATION ENERGY LOSSES IN BUILDINGS; A. Blomsterberg, D. Harrje; ASHRAE Transaction, Vol. 85, Pt.1, 1979.

PURPOSE:
This study examines air infiltration in houses.

SCOPE:
The parameters governing air infiltration in U.S. houses are outlined. Results were compared with those obtained from Swedish houses.

METHODOLOGY:
Infiltration data using tracer gas dilution methods and blower-door pressurization/depressurization methods were collected. Fifteen buildings were covered in the research. A computer model was developed to predict whole-house infiltration rates. Wind tunnel tests were undertaken to provide input required by the computer model.

MAJOR CONCLUSIONS:
It is very difficult to predict infiltration rates. The calculated values of air infiltration was 2.4 times greater than the measured infiltration for four of the buildings studies. The authors attribute these errors to a lack of knowledge of microclimate, building proportions, location of openings, bypasses, and internal flow resistance. More research is required to develop an accurate and relatively simple infiltration model.

A.5.7 AN AIR INFILTRATION MODEL FOR MODERN SINGLE FAMILY DWELLINGS; R. Macriss, J. Cole, T. Zawacki; Presented at the 72nd annual meeting of APCA, June 1979.

PURPOSE:
This paper examines infiltration in modern single family dwelling.

SCOPE:
The study reviews existing air infiltration models and presents a new modeling approach.

METHODOLOGY:
The authors review the then current modeling techniques including ASHRAE methods, Achenback-Coblentz correlation, Princeton studies, the Hittman approach, and NRC Canada method.

A more complex model involving the calculation of the position of the neutral zone, and an iterative solution of simultaneous mass-balance equations, chimney flow and energy equations, and chimney heat transfer equations is presented.

MAJOR CONCLUSIONS:
The authors claim that infiltration rates predicted by the model agree closely with measured infiltration rates.

A.5.8 FIELD STUDIES OF DEPENDENCE OF AIR INFILTRATION ON OUTSIDE TEMPERATURE AND WIND; N. Malik, Energy and Buildings, Vol. 1, No. 3; Apr. 1978.

PURPOSE:
This paper examines the effects of various parameters on infiltration rates.

SCOPE:
The effects of wind and temperature induced stack effects on air infiltration rate in residences are studied.

METHODOLOGY:
Air infiltration rates in two identical townhouses were measured during several winter months. Sulphur hexaflouride tracer gas decay techniques were used. Coincident weather data was also recorded.

Mathematical regression analyses were applied to the data, to derive equations of infiltration versus windspeed and outside temperature. The combined effect of wind and temperature on infiltration rate was examined.

MAJOR CONCLUSIONS:
At low wind speeds there is a linear relationship between air infiltration rate and decreasing outside temperature. At high wind speeds, infiltration is a non linear function of wind velocity combined with buoyancy effects.

Further research is required to develop a model that is more generally applicable.

A.5.9 IDENTIFYING VENTILATION TROUBLED HOUSES; J.H. White; Research Division CMHC; March 1984

PURPOSE:
This paper examines ventilation problems in houses.

SCOPE:
Natural ventilation in houses is explained. The air requirements of various appliances and devices are outlined. The problem of various appliances competing for air and the ability of natural ventilation to provide adequate air is discussed.

METHODOLOGY:
The results of extensive fan-depressurization data from across Canada was analyzed by the author. The author outlines mathematical techniques that help to determine whether potential ventilation problems exist.

MAJOR CONCLUSIONS:
The author tentatively suggests that an equivalent leakage area (ELA) of 700 sq. cm and/or a ventilation compliance (VC) of 13 L/s.Pa is required for houses without fireplaces. For houses with fireplaces ELA should be at least 1100 sq. cm and VC should be at least 22 L/s.Pa.

House envelopes should not be tightened until reliable mechanical ventilation systems are developed.

A.5.10 VENTILATION AND AIR QUALITY IN HOMES; an Enerwise publication; Saskatchewan Power Corporation; August, 1984.

PURPOSE:
This publication was written to increase public awareness of the potential problems with and possible cures for poor indoor air quality.

SCOPE:
New airtight houses and houses that have been tightened up by weatherstripping are examined.

METHODOLOGY:
Backdrafting is explained and potential causes are outlined. The symptoms of backdrafting are discussed. Causes of poor air quality and symptoms of various levels (i.e. mild, moderate, and severe) are listed. The authors outline three progressively complex solutions to backdrafting and poor air quality problems.

MAJOR CONCLUSIONS:
A combustion air supply will cure backdrafting problems. A more effective ventilation system may be required to cure problems with indoor air quality.

A simple vent will cure mild air quality problems and solve backdrafting problems. Ducting this vent to the cold air return duct of the furnace may solve moderate to severe air quality problems, but it should not be relied upon to provide combustion air for appliances. A duct heater to preheat the outside air may be required.

An air-to-air heat exchanger can cure severe air quality problems. Care must be exercised during installation of these devices.

A.5.11 METHODS FOR ESTIMATING AIR CHANGE RATES AND SIZING MECHANICAL VENTILATION SYSTEMS FOR HOUSES; C.Y. Shaw; Building Research Note #237, November 1985.

PURPOSE

The purpose of this report is to present simplified methods of calculating infiltration rates and required mechanical ventilation rates.

SCOPE

This paper deals with a bungalow, split level, and two-story housing with and without chimneys.

METHODOLOGY

The author examines temperature induced infiltration, wind induced infiltration, and combined wind and temperature induced infiltration. Both exposed and shielded buildings are modeled. One hundred and sixty standard houses and 40 low energy houses were analyzed to determine appropriate parameters for various types of houses. The effects of balanced mechanical systems and exhaust only systems on infiltration are discussed. The sizing of mechanical ventilation systems to provide adequate ventilation is outlined.

MAJOR CONCLUSIONS

The author presents simplified equations that allow the calculation of infiltration and required ventilation rates for various types of buildings with and without chimneys.

A.6 HEAT RECOVERY VENTILATORS

Listed below are summaries of publications that discuss heat recovery ventilators.

A.6.1 HEAT RECOVERY VENTILATION FOR HOUSING; National Centre for Appropriate Technology; DOE/CE/15095-9, February, 1984.

PURPOSE:

This publication summarizes the findings of research carried out between 1978 and 1981 by private firms under contract to the U.S. Government, Department of Energy.

SCOPE:
The report deals with air-to-air heat recovery in residential applications.

METHODOLOGY:
The authors explain what an air-to-air heat exchanger is and how it works. Advice in choosing the correct type and size of unit is presented. Installation techniques are outlined. Control systems and strategies are presented. The question of economics is addressed.

MAJOR CONCLUSIONS:
A method of providing continuous cost effective mechanical ventilation is essential in modern air-tight housing. This criteria is best met by using air-to-air heat recovery ventilation.

There are several barriers to more widespread installation of these devices including the following:

- a lack of awareness regarding indoor air quality problems,
- a lack of agreement on required amounts of fresh air, and
- a lack of standardized testing procedures.

A.6.2 MECHANICAL VENTILATION WITH HEAT RECOVERY FOR SUPERINSULATED HOUSES; J.J. Cooley; Conservation in Buildings: Northwest Perspective, Conference Proceedings, May 1985.

PURPOSE:
This paper compares various methods of house ventilation.

SCOPE:
The energy consumption of a standard house, built to 1980 code requirements was compared with two other houses built to "Model Conservation Standards" (MCS). One of the MCS houses was equipped with an air-to-air heat exchanger and the other MCS house was equipped with a variation of the "Swedish" system. The Swedish system uses a heat pump to extract heat from exhaust air and preheat domestic hot water.

METHODOLOGY:
Each of the three houses was equipped with a data acquisition system which monitored the energy consumption of the houses. Although the houses were unoccupied, occupancy was simulated using timed humidifiers in the kitchen and bathroom, and using a timer to dump 40 U.S. gallons of domestic hot water every twelve hours. The data was collected for a one year period. The degree day method and the bin temperature method were used to estimate transmission and infiltration losses.

MAJOR CONCLUSIONS:
The house equipped with an air-to-air heat exchanger used 69% of the energy of the standard house and the "Swedish" house used 57.8% of the energy of the standard house.

A.6.3 FIELD EXPERIENCES WITH AIR-TO-AIR HEAT EXCHANGERS - THE REAL STORY; M. Schell and D. Rogoza; Conservation in Buildings: Northwest Perspective, Conference Proceedings, May 1985.

PURPOSE:
This paper provides feedback on actual experiences with air-to-air heat exchanger installations.

SCOPE:
The results of a Canadian survey of super-insulated homes, equipped with air-to-air heat exchangers, is presented.

METHODOLOGY:
There were 376 survey questionnaires issued in Regina, Saskatoon, and Winnipeg. There were 147 responses. The results of the survey identify the major problems and frequency of occurrence. The authors discuss the six most common problems associated with heat recovery ventilators. The results of a tracer gas study are outlined.

MAJOR CONCLUSIONS:
Many problems have been experienced with actual air-to-air heat exchanger installations. The six major problems found are as follows:

1) Insufficient air flow due to excessive ductwork or inadequately sized ductwork.

2) Improperly located outside vents resulting in contaminated air or restricted air flow.

3) Excessive flexible ductwork resulting in reduced air flow.

4) Imbalanced air flows resulting in downdrafting or moisture damage to the building envelope. Out of 40 installations inspected 77% had imbalanced airflows in excess of 25%.

5) Undesirable interaction with forced air furnaces resulting in downdrafting.

6) Inadequately insulated ductwork resulting in condensation problems.

A.6.4 PRELIMINARY PERFORMANCE ASSESSMENT OF THREE VENTILATION SYSTEMS EMPLOYING AIR-TO-AIR HEAT EXCHANGERS; R.J. Corbett, B.A. Miller, D.A. Hagan; Conservation in Buildings: Northwest Perspective, Conference Proceedings, May 1985.

PURPOSE:
This paper provides information on the performance of three air-to-air heat exchanger installations.

SCOPE:
The three installations covered in this report were located in Eastern Montana. The installations were monitored for a three month period.

METHODOLOGY:
Detailed installation plans for air-to-air heat exchanger systems were developed and reviewed. After installation and balancing the installations were monitored continuously. Heat exchanger supply and exhaust temperatures, fan status, five indoor temperatures, and outside ambient temperatures were monitored.

MAJOR CONCLUSIONS:
The occupants of the three residences reported few problems with their systems.

Simple payback analyses should not apply to the installation of these systems because the added benefits provided by the system are not easily quantified.

System design, troubleshooting, and initial air-flow balancing will continue to be the major problems with these systems.

APPENDIX "B"

ENERGY BILLS FOR TEST HOUSES

ENERGY BILLS FOR TEST HOUSES

TEST HOUSE ONE

Month	metre reading	consumption	cost
January	829	36.14	113.73
February	854	26.42	86.96
March	870	16.74	58.63
April	884	14.43	51.78
May	892	8.15	33.13
June	898	6.14	25.33
July	901	3.11	16.75
August	905	4.14	19.41
September	910	5.11	21.94
October	923	13.38	43.58
November	948	23.84	76.17
December	969	20.38	61.88
Total			609.29

TEST HOUSE TWO

Month	metre reading	consumption	cost
January	079	22.13	73.11
February	107	27.99	90.94
March	121	13.80	49.91
April	132	10.92	41.36
May	140	7.96	32.57
June	145	5.01	23.05
July	148	3.06	16.70
August	148	0.00	8.57
September	153	5.06	21.81
October	162	8.97	32.04
November	174	12.05	40.09
December	57	13.18	47.15
Total			477.30

APPENDIX "C"

EXAMPLE COMPUTER SIMULATIONS OF TEST HOUSE 'AS IS'

ALL THE COMPUTER SIMULATIONS UNDERTAKEN FOR THIS STUDY WILL BE MADE AVAILABLE AT SPECIAL REQUEST. COPIES MAY BE OBTAINED FROM:

THE INNOVATIVE HOUSING GRANTS PROGRAM
ALBERTA MUNICIPAL AFFAIRS
9925 - 107 STREET
EDMONTON, ALBERTA T5K 2H9
CANADA

```
HOTCAN 3.02
NATIONAL RESEARCH COUNCIL OF CANADA, SASKATOON, SASKATCHEWAN, S7N 0W9

HOUSE DATA IS STORED IN FILE B:HOUSE1
WEATHER DATA IS FOR B:EDM85 (ALTERNATE USER FILE)

NAME    : IHGP TEST HOUSE ONE "AS IS"
ADDRESS: 11707 - 151 AVENUE, EDMONTON, ALBERTA

                                   BUILDING PARAMETERS
                                   *******************

ELEMENT         AREA                           HEAT LOSS      %SEASONAL
                 M2            RSI              GJ             LOSS
---------------------------------------------------------------------------
CEILING
                 98.11          1.69
      TOTAL      98.11          1.69            32.85          16.07

MAIN WALLS (LESS WINDOWS AND DOORS)
                 88.46          2.22
      TOTAL      88.46          2.22            22.55          11.03

DOORS (LESS WINDOWS)
                 3.53           .45
      TOTAL      3.53           .45             4.44           2.17

BASEMENT WALLS ABOVE GRADE
                 31.63          .26
      TOTAL      31.63          .26             58.19          28.47


FULL BASEMENT AREA: UNATTACHED, INSULATED INSIDE
------------------
UPPER 0.6 M OR 2 FT BASEMENT WALLS
                 26.01          .26
      TOTAL      26.01          .26             12.37          6.05

LOWER BASEMENT WALLS
                 47.69          .26
      TOTAL      47.69          .26             12.85          6.29

FLOOR PERIMETER AREA (1 M OR 3.3 FT WIDE)
                 38.87          .2
      TOTAL      38.87          0               10.38          5.08

FLOOR CENTER AREA
                 59.23          .2
      TOTAL      59.23          0               5.51           2.7


WINDOWS
-------
SOUTH WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .89)
                 3.62           .36
                 1.29           .36
                 1.29           .36
      TOTAL      6.2            .36             9.75           4.77
```

```
NORTH WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .89)
                4.46           .36
      TOTAL     4.46           .36            7.01           3.43

EAST WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .89)
                1.31           .36
      TOTAL     1.31           .36            2.06           1.01

WEST WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .83)
                3.44           .2
      TOTAL     3.44           .2             9.73           4.76
```

```
HOTCAN 3.0

VENTILATION
-----------
HOUSE VOLUME= 478.44153 M3
 .2 AIR CHANGES PER HOUR.
SEASONAL HEAT LOSS= 16.7 GJ ( 8.17 % OF TOTAL)

TEMPERATURES (DEG C) MAIN FLOOR= 21.111111
                     BASEMENT= 18.333333
                     RISE ABOVE  21.111111 DEG C= 2.7777778
THERMAL MASS LEVEL CHOSEN IS <A>

DAILY BASE ELECTRIC CONSUMPTION (KWH/D)= 30
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D)= 14
SENSIBLE HEAT GAIN FROM OCCUPANTS (KWH/D)= 2

SOUTH WINDOWS OVERHANG GEOMETRY:
  AVERAGE WINDOW HEIGHT= 1.44 M
  AVERAGE OVERHANG WIDTH= .3 M
  AVERAGE HEADER HEIGHT= 1.52 M
```

```
HOTCAN 3.0

DESIGN HEAT LOSS AT  -32 C = 17798 WATTS

                              AVERAGE MONTHLY POWER
                              *********************

MONTH        THERMAL LOAD    INTERNAL GAIN    SOLAR GAIN     AUX HEAT REQD
                WATTS           WATTS           WATTS           WATTS
---------------------------------------------------------------------------
 JAN            12607           1470            920             10217
 FEB            10978           1470            1259            8248
 MAR            9441            1470            1573            6398
 APR            6371            1389            1232            3749
 MAY            3892            1287            1065            1540
 JUN            2479            1145            839             494
 JUL            1570            964             548             57
 AUG            1909            1045            660             203
 SEP            3630            1268            971             1390
 OCT            5470            1363            990             3117
 NOV            8687            1470            920             6296
 DEC            11019           1470            773             8776

ESTIMATED ANNUAL SPACE HEATING= 132 GJ
ANNUAL INTERNAL GAINS FRACTION= .2
ANNUAL SOLAR FRACTION= .15

                           ANNUAL PREDICTED FUEL COSTS
                           ***************************

FUEL COSTS ARE FOR ALTERNATE USER FILE AS OF NOVEMBER 28, 19

ENERGY              COST          SPACE          HOT           LIGHTS AND
SOURCE            PER UNIT       HEATING        WATER          APPLIANCES
----------------  ---------------------------------------------------------
ELECTRICITY     $ .051/KWH      $ 1871         $ 260           $ 558
                                EFF.=100%     EFF.=100%      EFF.=100%

NATURAL GAS     $ .1/M3         $ 562          $ 78
                                EFF.= 63%     EFF.= 63%

#2 OIL          $ .335/LITRE
                                EFF.= 0%      EFF.= 0%

PROPANE         $ .25/LITRE
                                EFF.= 0%      EFF.= 0%

WOOD            $ 71.5/TONNE
                                EFF.= 0%      EFF.= 0%
```

```
HOTCAN 3.02
NATIONAL RESEARCH COUNCIL OF CANADA, SASKATOON, SASKATCHEWAN, S7N 0W9

HOUSE DATA IS STORED IN FILE B:HOUSE2
WEATHER DATA IS FOR B:EDM85 (ALTERNATE USER FILE)

NAME    : IHGP TEST HOUSE TWO
ADDRESS: 11006 - 38 STREET, EDMONTON, ALBERTA

                              BUILDING PARAMETERS
                              *******************

ELEMENT        AREA                          HEAT LOSS      %SEASONAL
                M2            RSI             GJ             LOSS
---------------------------------------------------------------------------
CEILING
                94.39         4.58
      TOTAL     94.39         4.58           8.05           6.39

MAIN WALLS (LESS WINDOWS AND DOORS)
                120.12        2.11
      TOTAL     120.12        2.11           22.24          17.66

DOORS (LESS WINDOWS)
                1.98          .45
      TOTAL     1.98          .45            1.72           1.36

BASEMENT WALLS ABOVE GRADE
                11.08         .35
                6.33          2.47
                9.1           2.47
                9.1           .35
      TOTAL     35.61         .56            24.97          19.82


FULL BASEMENT AREA: UNATTACHED, INSULATED INSIDE
------------------
UPPER 0.6 M OR 2 FT BASEMENT WALLS
                6.33          .35
                6.33          2.47
                5.57          2.47
                5.2           .35
      TOTAL     23.43         .66            5.81           4.62

LOWER BASEMENT WALLS
                7.92          .35
                12.66         2.47
                6.5           .35
                6.97          2.47
      TOTAL     34.05         .66            5.4            4.29

FLOOR PERIMETER AREA (1 M OR 3.3 FT WIDE)
                36.65         .2
      TOTAL     36.65         0              7.88           6.26

FLOOR CENTER AREA
                55.74         .2
      TOTAL     55.74         0              4.09           3.25
```

```
WINDOWS
--------
SOUTH WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .83)
                1.58              .2
     TOTAL      1.58              .2                3.09          2.45

NORTH WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .83)
                2.23              .2
     TOTAL      2.23              .2                4.36          3.46

EAST WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .83)
                4.74              .2
     TOTAL      4.74              .2                9.26          7.35

WEST WINDOWS (AVERAGE  2 GLAZINGS, SHADING COEFFICIENT= .83)
                3.44              .2
     TOTAL      3.44              .2                6.72          5.34
```

```
HOTCAN 3.0

VENTILATION
-----------
HOUSE VOLUME= 460.31875 M3
 .4 AIR CHANGES PER HOUR.
SEASONAL HEAT LOSS= 22.19 GJ ( 17.62 % OF TOTAL)

TEMPERATURES (DEG C) MAIN FLOOR= 15.555556
                     BASEMENT= 15.555556
                     RISE ABOVE  15.555556 DEG C= 0
THERMAL MASS LEVEL CHOSEN IS <A>

DAILY BASE ELECTRIC CONSUMPTION (KWH/D)= 14
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D)= 14
SENSIBLE HEAT GAIN FROM OCCUPANTS (KWH/D)= 1.6

SOUTH WINDOWS OVERHANG GEOMETRY:
  AVERAGE WINDOW HEIGHT= .86 M
  AVERAGE OVERHANG WIDTH= 0 M
  AVERAGE HEADER HEIGHT= 1.52 M
```

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HOTCAN 3.0

DESIGN HEAT LOSS AT  -32 C = 14974 WATTS


                              AVERAGE MONTHLY POWER
                              *********************

MONTH        THERMAL LOAD    INTERNAL GAIN    SOLAR GAIN     AUX HEAT REQD
                WATTS            WATTS           WATTS           WATTS
-----------------------------------------------------------------------------

 JAN             9081             787             430             7863
 FEB             7694             787             679             6227
 MAR             6423             787             1012            4623
 APR             3866             728             781             2356
 MAY             1822             594             556             672
 JUN             676              349             261             66
 JUL             0                0               0               0
 AUG             216              195             21              0
 SEP             1645             570             454             621
 OCT             3151             700             547             1904
 NOV             5825             787             454             4584
 DEC             7756             787             346             6623

ESTIMATED ANNUAL SPACE HEATING= 92 GJ
ANNUAL INTERNAL GAINS FRACTION= .15
ANNUAL SOLAR FRACTION= .12


                           ANNUAL PREDICTED FUEL COSTS
                           ***************************

FUEL COSTS ARE FOR ALTERNATE USER FILE AS OF NOVEMBER 28, 19

ENERGY              COST            SPACE          HOT          LIGHTS AND
SOURCE            PER UNIT         HEATING        WATER         APPLIANCES
-----------------------------------------------------------------------------
ELECTRICITY     $ .051/KWH       $ 1316         $ 260          $ 260
                                 EFF.=100%      EFF.=100%      EFF.=100%

NATURAL GAS     $ .1/M3          $ 383          $ 75
                                 EFF.= 65%      EFF.= 65%

#2 OIL          $ .335/LITRE
                                 EFF.= 0%       EFF.= 0%

PROPANE         $ .25/LITRE
                                 EFF.= 0%       EFF.= 0%

WOOD            $ 71.5/TONNE
                                 EFF.= 0%       EFF.= 0%
```

APPENDIX "D"

STANDATA 85-DI-017

DIRECTOR'S INTERPRETATIONS STANDATA

JANUARY 1986 85-DI-017
Page 1 of 2

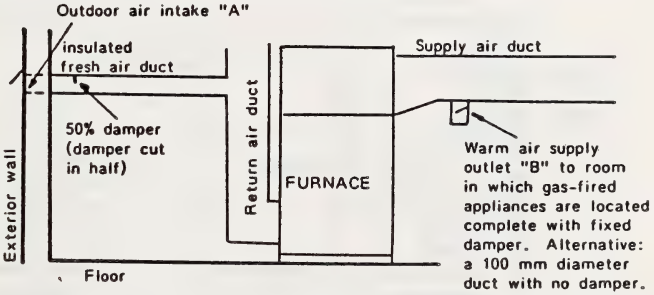
COMBUSTION AIR FOR DWELLING UNITS

This bulletin has been developed jointly by the Building Standards Branch and the Plumbing and Gas Safety Services Branch to clarify the requirements for combustion air for gas fired appliances that are installed in dwelling units.

The following two methods are acceptable to both branches and satisfy codes and regulations with regard to installation of gas fired furnaces and hot water heaters in dwelling units. (Other methods that give equivalent performance may be accepted by the two branches.)

METHOD 1

(Prior to using this method in R-2000 or similar homes designed for low infiltration, contact your local Building Inspector).


Outdoor air intake "A"
insulated fresh air duct
Supply air duct
50% damper (damper cut in half)
Return air duct
Exterior wall
FURNACE
Warm air supply outlet "B" to room in which gas-fired appliances are located complete with fixed damper. Alternative: a 100 mm diameter duct with no damper.
Floor

The furnace fan should be run continuously (a two speed fan would be advisable) so that combustion air will always be available for the hot water heater.

The warm air supply outlet supplying the space in which the gas fired appliances are located must be provided with a fixed damper set at the required air volume for the appliances, however a 100 mm diameter duct with no damper is also acceptable.

Normally 10 volumes of combustion air are required for each unit volume of natural gas. In addition to combustion air an equal volume of dilution air is required unless the venting system produces the exact draft necessary for each appliance. For the majority of installations 20 volumes of combustion and dilution air need to be supplied to the dwelling unit for each unit volume of natural gas used by the appliances and this air must be brought into the space containing the appliance.

The sizing of the combined combustion air and fresh air duct and the air intake will depend on the quantity of air required for combustion air and for all other air requirements in the building.

ISSUE OF THIS INTERPRETATION IS AUTHORIZED UNDER SENTENCE 1.5.4.2.(15) OF THE ALBERTA BUILDING CODE 1985 BY THE DIRECTOR OF BUILDING STANDARDS

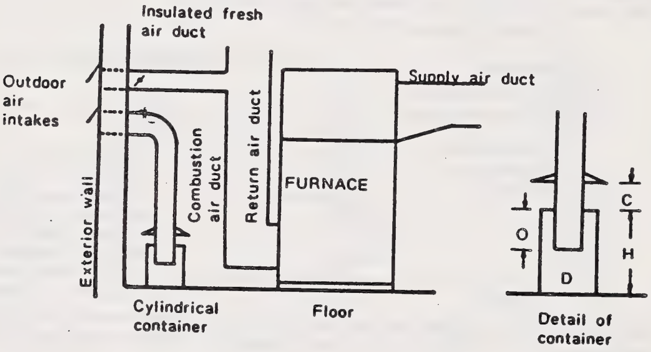
D. O. MONSEN, M.R.A.I.C.

Alberta

The following table is for guidance only. It assumes that the combined combustion air and fresh air duct is short and has not more than 2 elbows or other restrictions to air flow (not including the 50% damper).

Appliances	Combined Input kW	Minimum size of Combined Combustion Air and Fresh Air Duct
One Furnace &	up to 30	125 mm diameter
One Hot Water	over 30, not more than 45	150 mm diameter
Heater	over 45, not more than 60	175 mm diameter
Two Furnaces & One Hot	up to 60	125 mm diameter for each furnace
Water Heater	over 60, not more than 90	150 mm diameter for each furnace

METHOD 2



The cylindrical combustion air container must be bottomless so that it can be lifted up to remove debris that may fall in. The container diameter D must be at least 75 mm larger than the diameter of the combustion air duct. The combustion air duct must not extend more than 150 mm into the container (dimension X). The height of the container H must be at least 300 mm. The conical shroud shall be fastened to the combustion air duct, shall have an outer diameter at least 75 mm larger than the container diameter D and the clearance C between the bottom of the shroud and the top of the container shall be not less than 100 mm and not more than 150 mm.

The combustion air duct must be sized to have an area of at least 450 mm^2/kW based on the input rating of all appliances that it will serve.

Warning: The above information about supply of combustion air for gas fired appliances does not take into account other appliances and spaces in the dwelling unit that must be supplied with either make-up or combustion air (examples include attached garages, fireplaces, wood stoves, clothes dryers kitchen, washroom and other exhaust systems.)

NOTE: 15 kW = 50,000 Btu/h (approx.)

APPENDIX "E"

DEHUMIDIFICATION AIR COMPUTER PROGRAM

```
10 KEY OFF : CLS
20 PRINT
30 PRINT
40 PRINT
50 PRINT
60 PRINT
70 PRINT
80 PRINT
90 PRINT
100 PRINT
110 PRINT
120 PRINT
130 PRINT "                              ************************"
140 PRINT "                              *   DEHUMIDIFICATION   *"
150 PRINT "                              *     VERSION 1.0      *"
160 PRINT "                              *      26 NOV 85       *"
170 PRINT "                              ************************"
180 PRINT
190 PRINT
200 PRINT
210 PRINT
220 PRINT
230 PRINT
240 PRINT
250 INPUT "PRESS ENTER TO CONTINUE". SCROLL
260 CLS
270 PRINT
275 WP=0
280 PRINT
290 PRINT
300 INPUT "BAROMETRIC PRESSURE. PSI ":PT
310 LPRINT "MOISTURE ADDED STARTS AT .5LB AND INCREMENTS OF .5LB"
320 INPUT "INDOOR DRY BULB TEMPERATURE. DEG.F. ":TI
330 INPUT "OUTDOOR DRY BULB TEMPERATURE. DEG.F. ":TX
340 INPUT "DESIRED INDOOR RELATIVE HUMIDITY. % ":RHI
350 INPUT "OUTDOOR RELATIVE HUMIDITY. % ":RHX
351 LPRINT "BAROMETRIC PRESSURE IS ":PT:"PSI"
352 LPRINT "INDOOR DRY BULB TEMPERATURE IS ":TI:"DEG. F."
353 LPRINT "OUTDOOR DRY BULB TEMPERATURE IS ":TX:"DEG. F."
354 LPRINT "DESIRED INDOOR RELATIVE HUMIDITY IS ":RHI:"%"
355 LPRINT "OUTDOOR RELATIVE HUMIDITY IS ":RHX:"%"
356 LPRINT "MOISTURE ADDED TO INDOOR SPACE IS ":WP:"LB/HR."
360 PRINT
370 WP=WP+.5
380 PRINT
390 PRINT
400 N=1
410 GOTO 440
420 N=N+1
430 GOTO 470
440 TDB=TI
450 RH=RHI
460 GOTO 490
470 TDB=TX
480 RH=RHX
490 RH=RH/100
500 T=TDB
510 GOSUB 620
520 PS=P
530 PV=RH*PS
540 W=.62198*PV/(PT-PV)
550 H=.24*TDB+W*(.44*TDB+1061.8)
560 V=53.352*(TDB+460)/(PT-PV)*144)
570 P=PV
580 GOSUB 650
```

```
600 GOSUB 680
610 RETURN
620 REM SP
630 P=(.020663)+(.001174)*T+(1.5709E-05)*(T^2)+(3.9965E-07)*(T^3)
    +(4.5259E-10)*(T^4)+(2.0916E-11)*(T^5)
640 RETURN
650 REM ST
660 T=.19336+(484.89)*P-1744.6*(P^2)+4378!*(P^3)-6961.5*(P^4)+6884.6*(P^5)
   -4088.4*(P^6)+1330.5*(P^7)-181.95*(P^8)
670 RETURN
680 REM SWBTE
690 WTDP=W
700 FTDP=(TDP-TDB)*(.24+.44*WTDP)
710 WTDB=.62198*PS/(PT-PS)
720 FTDB=(WTDB-WTDP)*(1093.8-TDB*.56)
730 TWBLI=TDP-(TDB-TDP)*(FTDP/(FTDB-FTDP))
740 WBT=TWBLI
750 GOSUB 910
760 IF FWBT>0! THEN GOTO 770 ELSE GOTO 830
770 WBT=WBT-1
780 GOSUB 910
790 IF FWBT>0! THEN GOTO 770 ELSE GOTO 800
800 WBT=WBT+.1
810 GOSUB 910
820 IF FWBT >0! THEN GOTO 890 ELSE GOTO 800
830 WBT=WBT+1!
840 GOSUB 910
850 IF FWBT>0! THEN GOTO 860 ELSE GOTO 830
860 WBT=WBT-.1
870 GOSUB 910
880 IF FWBT>0! THEN GOTO 860 ELSE GOTO 890
890 TWB=WBT
900 RETURN
910 REM SFWBT
920 T=WBT
930 GOSUB 620
940 PSWBT=P
950 WWBT=.62198*PSWBT/(PT-PSWBT)
960 WTDP=W
970 FWBT=.24*(WBT-TDB)+.44*(WWBT*WBT-WTDP*TDB)+(WWBT-WTDP)*(1093.8-WBT)
980 IF N>1 GOTO 1040
990 WI=W
991 LPRINT
992 LPRINT
993 LPRINT
994 LPRINT
1000 LPRINT "HUMIDITY RATIO OF INDOOR AIR    ":
1010 LPRINT USING "#.#####": WI:
1020 LPRINT " LB/LB D.A. "
1030 IF N<2 GOTO 420
1040 WX=W
1050 LPRINT "HUMIDITY RATIO OF OUTSIDE AIR    ":
1060 LPRINT USING "#.#####":WX:
1070 LPRINT " LB/LB D.A."
1080 IF WX>WI GOTO 1140
1090 CFM=(WP/60)/(.075*(WI-WX))
1100 LPRINT "REQUIRED DEHUMIDIFICATION AIR    ":
1110 LPRINT USING "#######.#":CFM:
1120 LPRINT " CFM"
1125 LPRINT "MOISTURE ADDED TO INDOOR SPACE IS ":WP:"LB/HR."
1130 GOTO 1160
1140 LPRINT "INFINITE DEHUMIDIFICATION AIR REQUIRED"
1150 PRINT
1160 PRINT
1170 IF WP/24 GOTO 370
```

```
1190 INPUT "ANOTHER ANALYSIS (Y OR N)":A$
1200 IF A$="Y" GOTO 10
1210 END
```

APPENDIX "F"

U OF A TEST DATA FROM THE ELLERSLIE RESEARCH FACILITY

U OF A TEST DATA
FROM THE ELLERSLIE RESEARCH FACILITY

MONTHLY AVERAGE NATURAL AIR INFILTRATION RATES FOR MODULES FOR 1984

MODULE	1	2	3	4	5
January	.32	.48	.11	.25	.36
February	.19	.46	.11	.22	.32
March	.20	-	.11	.22	.34
April	.16	.34	.09	.20	.28
May	.17	.36	.08	.21	.29
June	.10	.22	.05	.13	.17
July	.10	.19	.04	.13	.17
August	.14	.22	.05	.14	.20
September	.16	.28	.06	.18	.26
October	.28	.40	.09	.21	.31
November	.28	.38	.09	.21	.34
December	.30	.44	.10	.20	.36

N.L.C. - B.N.C.
3 3286 08950088 4